OHIO DRAINAGE GUIDE

PREPARED JOINTLY BY
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OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
COOPERATIVE EXTENSION SERVICE, THE OHIO STATE UNIVERSITY
OHIO DEPT. OF NATURAL RESOURCES, DIVISION OF LANDS AND SOIL

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PREFACE

This publication was prepared to guide public and private engineers, technicians, and contractors in design and construction of surface and subsurface drainage systems.

These recommendations are based on the best research and field information available. They are subject to change as further data become available.

This publication supersedes "Ohio Drainage Guide of 1965" and was prepared jointly by the USDA Soil Conservation Service, the Cooperative Extension Service of The Ohio State University, the Ohio Agricultural Research and Development Center, and the Ohio Department of Natural Resources, Division of Lands and Soil.

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INTRODUCTION

For adequate agricultural drainage both surface and subsurface water must be removed from the land at rates which will prevent damage to the crops and soils. Some soils have sufficient natural slopes and natural drainageways which provide adequate surface drainage. These soils may or may not require subsurface drainage. If subsurface drainage is required on the more sloping lands, interceptor lines and random drains in the waterways are more commonly used than systematic subsurface drainage systems.

On land where natural surface drainage does not exist, shallow field drains and land smoothing or grading operations are required. Surface drainage usually is less costly than subsurface drainage. On fine textured impermeable soils, such as clay pans, surface drainage may be the only practical and economical method of drainage. Crops and soil management, therefore, must be selected accordingly. Soils which require improved internal drainage, and are sufficiently permeable to be drained economically, should first have a good surface drainage system. Then, if a high level of production is to be developed and maintained, they should be subsurface drained. Shallow field drains can eliminate ponded water and reduce the amount of water entering the soil profile. Subsurface drainage lowers the water table to provide an aerated rooting zone and to facilitate field operations. Too frequently land is subsurface drained with little attention to surface drainage.

Drainage ditches (open channels) are installed to provide outlets for subsurface and surface drainage systems.

HOW TO USE THE GUIDE

This guide, if used properly, will provide valuable information for the design of surface and subsurface drainage systems.

Step 1. Identify the soil to be drained. Many Ohio counties have published soil surveys. If these are not available, consult your local Soil & Water Conservation District office.

Step 2. Using the soil name refer to Table I, Page 3 which consists of an alphabetical listing of all soils mapped in Ohio. Each soil is placed in a Drainage Group.

Step 3. Using the Drainage Group for the soil, refer to Table II, Page 8. This table gives recommendations for design of a drainage system based on the Drainage Group.

TABLE I

ALPHABETICAL LISTING OF ALL OHIO SOILS AND ASSOCIATED DRAINAGE GROUPS

SOIL SERIES	DRAINAGE GROUP	SOIL SERIES	DRAINAGE GROUP
Abington	B-1	Carlisle	A-1
Abscota	Gf	Casco	G
Adrian	A-2	Castalia	G
Alexandria	G	Cavode	E-3
Alford	G	Celina	F-3
Algiers	D-1	Ceresco	D-1
Allegheny	G	Chagrin	Gf
*Allis	C-1	Channahon	G
Alvin	G	Chenango	G
Arkport	G	Chili	G
Ashton	G	Chilo	B-2
Atherton	C-1	Cincinnati	G
Atkins	D-1	Claverack	F-2
Avonburg	E-4	Clermont	C-1
Bartle	E-1	Clymer	G
Beasley	G	Cohoctah	D-1
Belmore	G	Colonie	G
Bennington	E-2	Colwood	B-1
Bentonville	E-4	Colver	G
*Berks	G	Condit	C-1
Birkbeck	F-2	Conneaut	C-1
Blago	B-4	Conotton	G
Blanchchester	B-2	Coolville	F-3
Blount	E-2	Corwin	F-2
Bogart	F-2	Coshocton	F-3
Bono	B-4	Crane	E-1
Bonpas	B-1	Crider	G
Coyer	G	Crosby	E-1
Braceville	F-3	Cruze	F-3
Bratton	G	Damacus	C-1
Brenton	E-1	Dana	F-2
*Brooke	G	Danbury	E-2
Brookside	G	Darroch	E-1
Brookston	B-1	Defiance	D-2
Broughton	F-3	Dekalb	G
Burgin	B-4	Del Rey	E-2
Byington	F-3	Digby	E-1
Cambridge	F-3	Dubois	E-4
Cana	F-3	Dunbridge	G
Canadice	C-1	Duncannon	G
Caneadea	E-3	Dunning	D-1
Canfield	F-3	Eden	G
Captina	F-3	Edenton	G
Cardington	F-3	Edwards	A-2

*Bedrock occurs at a depth of 20 to 40 inches.
Gf - Well drained soils in floodplains.

SOIL SERIES	DRAINAGE GROUP	SOIL SERIES	DRAINAGE GROUP
Eel	F-1	Iva	E-1
*Eifort	G	Jacksonville	E-4
Elliott	F-2	Jessup	G
Ellsberry	F-3	Jimtown	E-1
Ellsworth	F-3	Johnsburg	E-4
Elnora	F-2	**Joliet	D-3
Ernest	F-3	Kalamazoo	G
**Fairmount	G	Kane	E-1
Fawcett	E-4	Keene	F-3
Fincastle	E-1	Kendallville	G
Fitchville	E-1	Kerston	A-1
Foresman	E-3	Kibbie	E-2
Fox	G	Killbuck	D-1
Frankstown	G	Kings	B-4
Frenchtown	C-1	Kingsville	D-5
Fries	D-4	Kokomo	B-1
Fulton	E-3	Laidig	G
Galen	F-2	Landes	Gf
Geeburg	F-3	*Latham	G
Genesee	Gf	Latty	B-4
Gilford	D-5	Lawrence	E-4
*Gilpin	G	*Lawshe	G
Ginat	C-1	Lenawee	B-2
Glenford	F-2	Lewisburg	F-3
Granby	D-5	Library	E-3
Grayford	F-3	Licking	F-3
Gresham	E-4	Lindside	F-1
Guernsey	F-3	Linwood	A-2
Hackers	G	Lippincott	B-1
Hagerstown	G	Lobdell	F-1
Haney	F-2	Lockport	E-3
Hanover	G	Lorain	B-4
Hartshorn	G	*Lordstown	G
Haskins	E-1	Lorenzo	G
Haubstadt	F-3	Loudon	F-3
Hennepin	G	*Loudonville	G
Henshaw	E-1	Lucas	F-3
Hickory	G	Luray	B-2
Holly	D-1	Maddox	G
Homer	E-1	Mahalasville	B-1
*Hornell	F-3	Mahoning	E-3
Hoytville	B-3	Manlove	G
Huntington	Gf	Marengo	B-2
Illion	C-1	Markland	F-3
Ionia	F-2	Martinsville	G

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**Bedrock occurs at a depth of 10 to 20 inches.
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SOIL SERIES	DRAINAGE GROUP
McGary	E-3
Medway	F-1
Melvin	D-1
Mentor	G
Mermill	B-2
Metamora	D-6
Metea	F-3
Miamian	G
Millgrove	B-1
*Millsdale	B-2
*Milton	G
Miner	B-4
Minoa	D-5
*Mitiwanga	E-3
Monongahela	F-3
Monroeville	B-4
Montgomery	B-4
Morley	F-3
Moshannon	Gf
Muskego	A-1
*Muskingum	G
Nappanee	E-3
Negley	G
Nekoosa	G
Neotoma	G
Newark	D-1
Nicholson	F-3
Nolin	F-1
Oakville	G
Ockley	G
Odell	E-1
Olena	G
Olmsted	B-1
**Opequon	G
Orrville	D-1
Oshtemo	G
Otisville	G
Ottokee	F-2
Otwell	G
Painesville	D-6
Papakating	D-1
Parke	G
Patton	B-1
Paulding	D-4
Peking	F-2
Peoga	C-1
Pewamo	B-2
Philo	F-1
Pierpont	F-3
Pike	G
Plainfield	G
Platea	E-4
*Plattville	G
Pope	Gf
Princeton	G
Prout	E-3
Purdy	C-1
Pyrmont	E-2
Ragsdale	B-1
Rainsboro	F-3
Ramsey	G
*Randolph	E-3
*Rarden	F-3
Raub	E-1
Ravenna	E-4
Rawson	F-2
Red Hook	E-1
Reesville	E-1
Remsen	E-3
Reynolds	D-6
Rimer	D-6
**Ritchey	G
Rittman	F-3
Rodman	G
**Romeo	G
Roselms	D-4
Ross	Gf
Rossmoyne	F-3
Russell	G
Sadler	F-3
St. Clair	F-3
Sardinia	F-2
Schaffenaker	G
Sciotoville	F-3
Sebring	C-1
Sees	F-3
Senecaville	F-1
Seward	G

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SOIL SERIES	DRAINAGE GROUP	SOIL SERIES	DRAINAGE GROUP
Sheffield	C-1	Weinbach	E-4
Shelocta	G	Wellston	G
Shinrock	F-3	Westland	B-1
Shoals	D-1	Westmore	G
Sisson	G	Wetzel	B-2
Sleeth	E-1	Wharton	F-3
Sloan	D-1	Wheeling	G
Spinks	G	Willette	A-3
Stafford	D-5	Williamsburg	G
Stendal	D-1	Williamson	F-2
Stonelick	G	Wilmer	E-1
Summitville	G	Woodsfield	G
Swanton	D-5	Woolper	G
Taggart	E-4	Wooster	G
Tedrow	D-5	*Wynn	F-3
Thackery	F-2	Xenia	F-3
Tilsit	F-3	Zaleski	G
Tioga	Gf	Zanesville	G
Tippecanoe	F-3		
Tiro	E-1		
Titusville	F-3		
Toledo	B-4		
Trappist	G		
Trumbull	C-1		
Tuscarawas	F-3		
Tuscola	F-2		
Tygart	C-1		
Tyler	E-4		
Uniontown	F-2		
Upshur	G		
Vandalia	G		
Vaughnsville	E-1		
Venango	E-4		
Vincent	F-3		
Wabasha	D-2		
Wadsworth	E-4		
Wallington	E-4		
Wallkill	D-1		
Warners	A-2		
Warsaw	G		
Washtenaw	D-1		
Wauseon	D-6		
Wayland	D-1		
Wea	G		
Weikert	G		

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EXPLANATION OF TABLE II

Column 1 - DRAINAGE GROUP - Soils are grouped on the basis of drainage characteristics requiring similar treatment. The group to which each soil is assigned is found in TABLE I.

COMMON SOIL - This is a common soil in that drainage group.

LANDSCAPE POSITION - The topographic location of the common soil.

PARENT MATERIAL - The unconsolidated, chemically weathered mineral or organic matter from which the soil profile was developed.

Column 2 - DOMINANT PERMEABILITY RANGE IN/HR - The rate in inches per hour that water moves through the B horizon for the majority of soils in that group.

Column 3 - DOMINANT USDA TEXTURE "B" HORIZON - The predominant textural classification of the "B" horizon. The horizon in which most subsurface drainage practices will occur.

Column 4 - DOMINANT UNIFIED CLASSIFICATION "B" HORIZON - A classification of the soil horizon normally affected with drainage practices. This is an engineering classification of the soil group according to their partical size, gradation, plasticity index, liquid limit, and organic matter. (See EFM Chapter 4)

Column 5 - DRAINAGE PROBLEMS AND RECOMMENDATIONS - The most common problems associated with the group with general recommendations.

Column 6 - KIND OF DRAINAGE - This lists the kinds of drainage applicable to the group. They may be used separately or in combination.

Column 7 - DRAIN DEPTH-INCHES - The depth in inches the drain should be to give the best drainage for that particular soil group.

Column 8 - DRAINAGE SPACING-FEET - The spacing in feet between surface or subsurface drains. The spacings are based on the soil group and the depth of trench or ditch used. The spacing is closer for special crops to provide a higher degree of drainage. The spacing is also based on crop economics.

TABLE II -- DRAINAGE GROUPS AND RECOMMENDATIONS

DRAINAGE GROUP	1 COMMON SOIL, USUAL LANDSCAPE, PARENT MATERIAL	2 DOMINANT PERMEABILITY RANGE-IN/HR	3 DOMINANT USDA TEXTURE "B" HORIZON	4 DOMINANT UNIFIED CLASSIFICATION "B" HORIZON
A	VERY POORLY DRAINED ORGANIC SOILS			
A-1	Carlisle; depressional areas on uplands, terraces or bottomlands; organic materials more than 40 inches thick.	6.0+	-	Pt
A-2	Linwood; depressional areas on uplands, terraces, or bottomlands; organic materials 20-40" thick over sandy or loamy material.	Muck 6.0+ Mineral 0.6-6.0	s,sil,sicl	Pt SM,ML
A-3	Willette; depressional areas on uplands, terraces, or bottomlands; organic material 20-40" thick over clayey materials.	Muck 6.0+ Mineral <0.2	- sicl,sic,c	Pt MH,CH,CL
B	VERY POORLY DRAINED SOILS			
B-1	Brookston; till plain or terraces; loamy or sandy glacial till, loess, or outwash material.	0.2 to 2.0	l,sil,sicl	CL,ML
B-2	Pewamo; till plain or terraces; clayey or loamy glacial till or lacustrine sediments.	0.06 - 0.6	sicl,cl,scl	CL,ML
B-3	Hoytville; lake plain, clayey wave-modified glacial till.	.06 - 0.2	c,sic	CL,MH
B-4	Toledo; lake plain, till plain, or terraces; clayey lacustrine sediments.	<0.2	c,sic	CL,MH,CH
C	POORLY DRAINED SOILS			
C-1	Clermont; till plain, terraces, lake plain, or outwash plain; glacial till, outwash or lacustrine sediment.	.06 - 0.6	sil,sicl,l	CL,ML
D	SOMEWHAT POORLY TO VERY POORLY DRAINED SOILS			
D-1	Sloan; bottomlands, loamy or clayey alluvial sediments.	.06 - 2.0	sil,sicl	ML,CL
D-2	Wabasha; bottomlands, clayey alluvial sediments.	<0.2	c,sic	MH,CL,CH

5 DRAINAGE PROBLEMS AND RECOMMENDATIONS	6 KIND OF DRAINAGE	7 TRENCH DEPTH INCHES	8 DRAINAGE SPACING-FEET GENERAL CROPS	 SPECIAL CROPS
Permanent high water table - divert water from surrounding slopes; consider water level control to minimize subsidence; drain depth 6" less than organic soil depth.	Subsurface Surface	42-54	80-200 150-250	50-80
Permanent high water - divert water from surrounding slopes; consider water level control to minimize subsidence. Drainage by open ditches is preferred.	Subsurface Surface	36-42	50-100 100-200	40-60
Permanent high water table - divert water from surrounding slopes; consider water level control to minimize subsidence. Drainage by open ditches is preferred.	Subsurface Surface	36-42	40-60 100-200	30-40
Prolonged seasonal high water table; ponding, land smoothing where needed.	Subsurface Surface	36-42	65-100 Random	40-60
Prolonged seasonal high water table; ponding; land smoothing where needed.	Subsurface Surface	36-42	55-75 Random	40-60
Prolonged seasonal high water table; ponding; land smoothing where needed; surface drainage important.	Subsurface Surface	36-42	45-65 100-250	25-45
Prolonged seasonal high water table; ponding; land smoothing where needed; surface drainage important.	Subsurface Surface	30-42	40-60 100-200	25-45
Prolonged seasonal high water table; land smoothing where needed; usually needs surface drainage; subsurface drainage seldom profitable. Nearly all soils have low pH.	Subsurface Surface	30-36	40-60 100-300	25-45
Flooding; seasonal high water table; outlets may be difficult to obtain; land smoothing where needed.	Subsurface Surface	30-42	45-70 Random	25-60
Flooding;seasonal high water table; outlets may be difficult to obtain; land smoothing where needed.	Subsurface Surface	30-42	45-70 Random	25-50

TABLE II -- Continued

DRAINAGE GROUP / 1 COMMON SOIL, USUAL LANDSCAPE, PARENT MATERIAL	2 DOMINANT PERMEABILITY RANGE-IN/HR	3 DOMINANT USDA TEXTURE "B" HORIZON	4 DOMINANT UNIFIED CLASSIFICATION "B" HORIZON
D SOMEWHAT POORLY TO VERY POORLY DRAINED SOIL - continued			
D-3 Joliet; till plain; 10-20" of till over limestone bedrock.	0.6 - 2.0	sil,cl	CL
D-4 Paulding; lake plain; clayey lacustrine sediments.	< 0.06	c	CH,MH
D-5 Granby; outwash plain, terraces, lake plain or beach deposits; sandy lacustrine or outwash sediments.	6.0+	lfs,s	SM,SP
D-6 Wauseon; outwash plain; terraces or lake plain; 20-40" of sandy sediments over clayey material.	Above 2-3' 6.0+ Below 2-3' < 0.2	fsl,lfs,s c,sic,sicl	SM,SP CH,CL
E SOMEWHAT POORLY DRAINED SOILS			
E-1 Crosby; till plain, outwash plain or terraces; glacial till, loess, outwash or lacustrine sediments.	0.20 - 2.0	cl,sil,l, sicl	CL,ML
E-2 Blount; till plain or lake plain; glacial till or lacustrine sediments.	.06 - 0.6	sicl,sic	CL
E-3 Nappanee; till plain or lake plain; glacial till or lacustrine sediments, or shale.	< 0.2	sic,c	CH,MH,CL
E-4 Ravenna; till plain, glacial till; fragipan layer in the B horizon	< 0.2 0.	sil,sicl,l	ML,CL
F MODERATELY WELL DRAINED SOILS			
F-1 Eel; bottomlands, loamy or clayey alluvial sediments.	.06 - 6.0	sil,l,sicl, sic	ML,CL,MH,SM
F-2 Corwin; terraces or outwash plains; generally loamy outwash or lacustrine sediments.	.06 - 6.0	sil,sicl,l	ML,CL,SM,GM
F-3 Morley; uplands; glacial till, lacustrine sediments, or residual materials.	.06 - 6.0	sicl,sil,l, sic	CL,ML,MH,GM
G WELL DRAINED SOILS	.06 - 6.0	variable	variable

5 DRAINAGE PROBLEMS AND RECOMMENDATIONS	6 KIND OF DRAINAGE	7 TRENCH DEPTH INCHES	8 DRAINAGE SPACING-FEET GENERAL CROPS	 SPECIAL CROPS
Limestone bedrock within a depth of 20" from the surface; use surface drains and diversions.	Surface	-	Random	-
Seasonal high water table; ponding; subsurface drainage not usually feasible; surface drain; land smoothing where needed.	Subsurface Surface	30-36	40-55 100-150	25-45
Seasonal high water table; sandy material likely to flow when wet; ditch and trench walls unstable.	Subsurface	30-48	60-120	40-110
Seasonal high water table; sandy material likely to flow when wet; ditch and trench walls unstable.	Subsurface	30-48	50-75	25-60
Seasonal high water table; land smoothing where needed.	Subsurface Surface	30-42	50-75 Random	30-50
Seasonal high water table; land smoothing where needed.	Subsurface Surface	30-36	50-70	25-50
Seasonal high water table; land smoothing where needed; subsurface drainage not always profitable.	Subsurface Surface	30-36	45-55 100-200	25-45
Seasonal high water table; slow or very slow permeability in fragipan horizon. Glacial till may be acid, corrodes concrete tile.	Subsurface Surface	30-36	45-70 100-400	25-50
Flooding; slight seasonal wetness.	Subsurface Surface	36-42	Random Random	25-50
Slight seasonal wetness; random drain small wet spots.	Subsurface Surface	30-42	Random Random	35-60
Slight seasonal wetness; random drain small wet spots and along waterways if wet; may be acid, corrodes concrete tile.	Subsurface Surface	30-42	Random Random	25-50
These soils require no drainage other than an occasional seep spot. Some soils occur in flood plain - see Table I, Gf.	Subsurface Surface	30-36	Random Random	

UTILITIES

Ohio is a densely populated state with many miles of public and private utilities such as pipelines, telephone, telegraph, or electric transmission lines, railroads, and highways. These utilities may be overhead, surface, or underground. In the design and construction of drainage practices it is extremely important that the location of any utility in relation to the drainage project is known. Many of the utilities are well marked yet some are not.

In the surveys for design, check with all available sources as to the possible location of hidden utilities. Landowners and contractors should contact all underground utility companies who have facilities in the area of work. The utility company representative should locate the line for alignment and depth. During construction, again contact the utility company for on-site assistance. Disrupting utilities, either private or public, can be costly and dangerous.

OUTLETS FOR DRAINAGE SYSTEMS

All drainage systems require outlets of adequate capacity, depth and stability to meet design requirements. If the outlet is inadequate, the value of the entire drainage system can be greatly reduced or lost.

Adequacy of Outlets

An outlet channel must have the capacity to carry flow from the particular drainage system being designed as well as flow from its entire drainage area. When the outlet carries flow from subsurface drains, its depth should be such that subsurface drains can be discharged into it above normal low water flow.

Installation of channels, or improvement of existing channels, usually increases peak discharges downstream from the end of the improvement. Care should be taken to prevent increased stages downstream from creating significant damage. The channel must be stable when there is flow at design capacity.

Required Capacities

Drainage design criteria are based on the fact that crops can tolerate a limited amount of flooding but must not be flooded for long periods of time, usually no longer than 24 to 48 hours. The term "drainage coefficient" is used to denote the depth, in inches, of water that a drainage channel (or drainage system) can remove from its entire watershed in 24 hours. The drainage coefficient may range from 3/8-inch for subsurface drainage of field crops grown on Ohio mineral soils to more than 2 inches for surface drainage of truck crops grown on muck soils (see Page 34 for recommended drainage coefficients). The U.S.D.A.

Soil Conservation Service publications "Drainage of Agricultural Land" (Section 16, SCS Nat. Eng. Handbook) and "Engineering Field Manual" provide details on the design of outlets for protection of land from overflow and for various levels of drainage for agricultural crops. See Table XI in Appendix.

Hydraulic and Environmental Considerations

Ideal open channels would have neither excessive scour nor deposition of sediments, but in practice, ideal conditions are very difficult to achieve. Design engineers should select velocities that are neither excessively erosive nor so low as to cause large amounts of sediment deposition. Grades should be as uniform as possible, gradual curves should be designed where needed, and control structures should be used to admit surface water to the channels.

Velocities less than 1.5 feet per second should be avoided, since siltation is likely to occur and result in growth of weeds and brush as well as reduction of channel cross sectional area. Table III provides a guide to maximum allowable velocities.

Table III. Maximum Allowable Velocities in Open Channels for Given Soil Textures

Soil Texture	Velocity* (ft./sec.)
Sand, loamy sand, sandy loam	2.5
Silt loam, loam	3.0
Sandy clay loam, sandy clay	3.5
Clay loam, silty clay loam	4.0
Silty clay	5.0
Fine gravel, cobbles, or graded loam to cobbles	5.0
Graded mixture silt to cobbles	5.5
Coarse gravel, shales, hardpans	6.0

*Use most critical soil layer if stratified.

Channel Depth

Open ditches that serve as outlets for closed drains should be designed for a normal water surface at or below the invert of the outlet end of the closed drain. The normal water surface is defined as the elevation of the usual low flow during the growing season. The clearance between a subsurface drain invert and the ditch bottom should be at least 1 foot, except where lower values are specified because of unusual site conditions.

Cross Section

The channel cross section should meet the combined requirements of capacity, velocity, depth, side slopes, bottom width, and, if needed, allowances for initial sedimentation. Side slopes should be stable and meet requirements for maintenance. Based upon soil conditions, side slopes should be no steeper than:

2:1	- loam
1½:1	- clay and other fine-textured soils
1:1	- sand, peat and muck

For ease and safety of mowing and maintenance, side slopes no steeper than 2:1 are recommended for fine textured soils. Special equipment may be needed for safe maintenance of deep ditches.

In some situations, ditches may need to be crossed by farm machinery. This can be a factor in deciding on the bottom width and side slopes.

Berms and Spoil Banks

Excavated soil may either be spread or left in spoil banks along the channel. If spoil banks are used, a berm or flat area must be left adjacent to the channel bank. This will provide for roadways and operation of maintenance equipment. Berms will also prevent excavated material from rolling back into the channel and will serve to lessen sloughing of banks by reducing loads. Berms should be at least 10 feet wide and should be 15 feet wide along channels over 8 feet deep (Figure 1). Spoil banks should have stable side slopes and provisions must be made to convey water through the spoil and into the ditch without causing serious erosion. Berms and spoil banks should be seeded immediately after construction to reduce erosion to a minimum. They should be kept in permanent grass.

In cropland areas, it is often desirable to spread the spoil (Figure 2). Spreading may begin at or near the channel bank, or a berm may be left as described above. If spreading begins at the channel bank, it should be graded to slope away from the channel at a slope not steeper than 4 to 1 and preferably 8 to 1 if it is to be farmed (see Figures 1 and 2). All berms and spoil banks should be seeded immediately after construction to reduce erosion and keep sediment loss to a minimum. Seeding ditch banks and berms to permanent cover is recommended and will prolong the life of many ditches by helping to stabilize the banks, thereby reducing erosion and the growth of brush and trees.

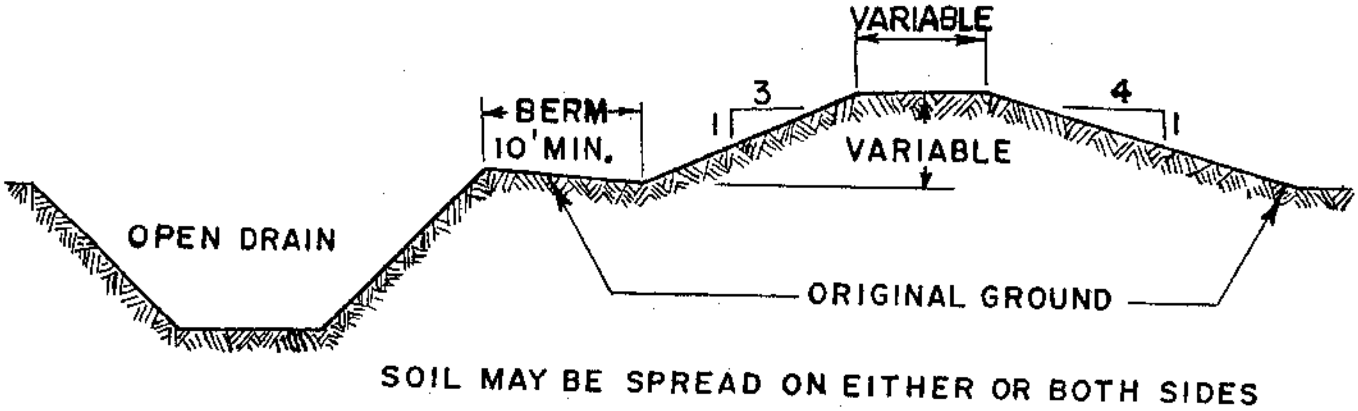


Figure 1. Open ditch spoil bank spreading (with berm).

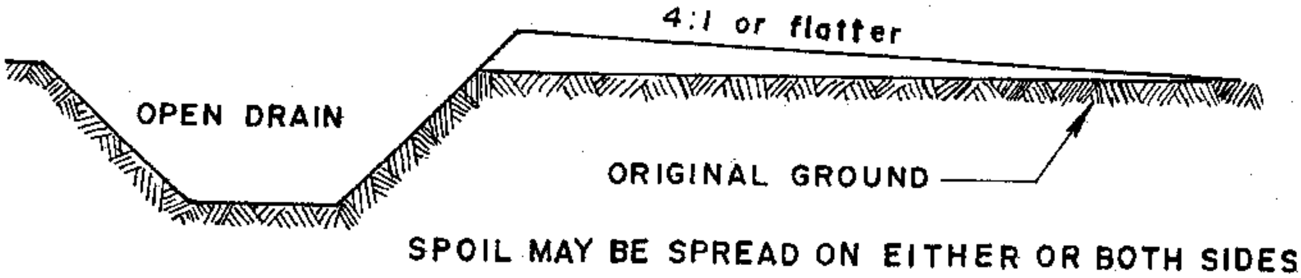


Figure 2. Open ditch spoil spreading (no berm).

Brush and weeds retard the velocity of water flowing in the ditch, resulting in reduced drainage capacity. Smooth-stemmed grasses are preferred, since they provide a smooth surface for water flow.

Structural Protection

Ideally, surface water should enter the channel only through lateral ditches graded on stable grades to the bottom of the channel or over or through stabilizing structures. Structures for this purpose may be chutes, drop spillways, or conduits with proper inlets. They may be located at the entrance of lateral channels, at the head of ditches, or along the channel at selected intervals to serve as outlets for individual drainage systems.

Culverts and Bridges

Culverts and bridges across ditches should be designed for loads carefully determined from the weight of farm machinery, trucks and other vehicles expected to use them.

Openings must be large enough to avoid reduction of ditch flow capacity. SCS publication "Drainage of Agricultural Land" - (Sec. 16, SCS Nat. Eng. Handbook) has details on the design and installation of culverts and bridges for open ditches. Where bridges and culverts are not feasible, fords with suitable ramps for livestock and machinery may be used.

Maintenance of Outlets

Maintenance of a drainage system is the key to longer life and lower operating costs and must be considered in all proposals beginning with design. An annual inspection and a systematic maintenance program is strongly recommended.

The grass on ditch banks, berms and spoil banks may need occasional mowing. Care should be taken to avoid destruction of wildlife. Brush and weeds may be controlled by herbicide sprays. Always check local, State and Federal regulations on the use of herbicides. Read and follow instructions on the label.

Aquatic weeds should be kept out of ditch bottoms, since they delay drainage by reducing flow rates and causing sediment deposits. These weeds may be controlled by herbicides, but their application will depend on downstream uses of water and legal liability. Legal aspects should be investigated before use. Sediment deposits and accumulations of debris should be removed from outlet ditches to maintain their design capacity.

SURFACE DRAINAGE

Surface drainage is the orderly removal of excess water from the surface of the land through improved natural channels, or constructed ditches, and through shaping of the land surface. The objectives of surface drainage are:

> To prevent water from ponding on land surfaces;
> To remove excess water before crops are damaged;
> To remove excess water with a minimum amount of erosion.

Surface drainage applies primarily on flat land with slow infiltration, low permeability, shallowness of soil over rock and areas subject to overflow from streams. The basic types of surface drainage systems are:

Surface Treatment

1. Land Grading

   Land grading for drainage consists of shaping the land surface by cutting, filling and smoothing to pre-determined, continuous grades. It is the most complete surface treatment.

   Flat land should be provided with a minimum of .05 percent slope. This can be established only if sufficient surface soil is present on the lower end of the smoothed area to provide the necessary borrow. Adequate soil investigations should be made to determine the depth of surface soil. Depth of grading should be controlled to prevent exposing unfavorable subsoil.

2. Land Smoothing

   Land smoothing is recommended to supplement surface drainage systems and to increase their effectiveness. Land smoothing means grading or planing the ground surface mechanically to eliminate or reduce elevated areas and fill minor depressions. The purpose is to provide a more uniform plane for surface runoff to move into field drains.

   On depressional land, only sufficient soil should be moved to fill in minor depressions and remove small ridges and humps. Depressions up to about 6 inches deep and a few feet across may be filled. Larger depressions may be drained by a shallow field ditch. The surrounding area may then be smoothed to drain to this depression.

   The finished surface of a smoothed field should be free from minor depressions and graded so that runoff will flow unobstructed from the entire area to collection or field ditches.

3. Land Grading and Smoothing

   a. Eliminates small low areas and pockets that collect and hold water.

   b. Assists in the preparation of a seedbed.

   c. Permits uniform planting depths and insures faster and more uniform germination of seed and better stands.

   d. Makes cultivation more uniform and weed removal more complete.

e. Makes more efficient use of cutting and picking machinery by permitting operations closer to the ground.

f. Permits higher operating speeds.

Field Ditches

Two common types of collection ditches are the single ditch and the "W" ditch (twin or double ditch). The single ditch is used where spoil can be moved and spread in low areas of the field without obstruction flow into the ditch. The double or "W" ditch is used in areas where (1) the land drains toward the ditch from both directions, (2) the land is very flat and row drainage will enter from each side, and (3) the excavated material is not needed to fill depressions (see Page 25).

The cross section of collection ditches may be either trapezoidal, "V", or parabolic. The minimum depth should be 9 inches and the minimum cross sectional area 5 square feet. Slopes should be 4 to 1 or flatter if farming operations are parallel to the ditch and 8 to 1 or flatter if farming operations cross the ditch. When topographic conditions prohibit construction of 8 to 1 side slopes steeper slopes may be permitted.

1. Parallel System

The parallel system is suitable for flat, poorly drained soils that have numerous shallow depressions. Where fields can be cultivated up and down the slope, parallel ditches are also used across the slope to break the field into shorter units of length. The cross-section is flat enough to permit farm equipment to operate across the ditch and the spacing is dependent upon the land slope. The success of the system depends largely upon proper spacing of the parallel ditches and the smoothing or grading between ditches.

Figure 3 illustrates the general layout and design specifications for the parallel ditch system.

Additional suggestions for use and design of the parallel system include:

a. Plan the system so that crop rows run in the direction of greatest slope.

b. Lay out collection ditches across the slope but never with less fall than .05 foot in 100 feet. Grade the surface between the ditches, if necessary, to have all rows drain to the ditch.

c. Be sure each collection ditch has a good outlet.

SHALLOW DITCHES TO INTERCEPT AND REMOVE SURFACE WATER FROM THE FIELD AND REDUCE THE LENGTH OF ROW DRAINAGE ON FLAT LANDS

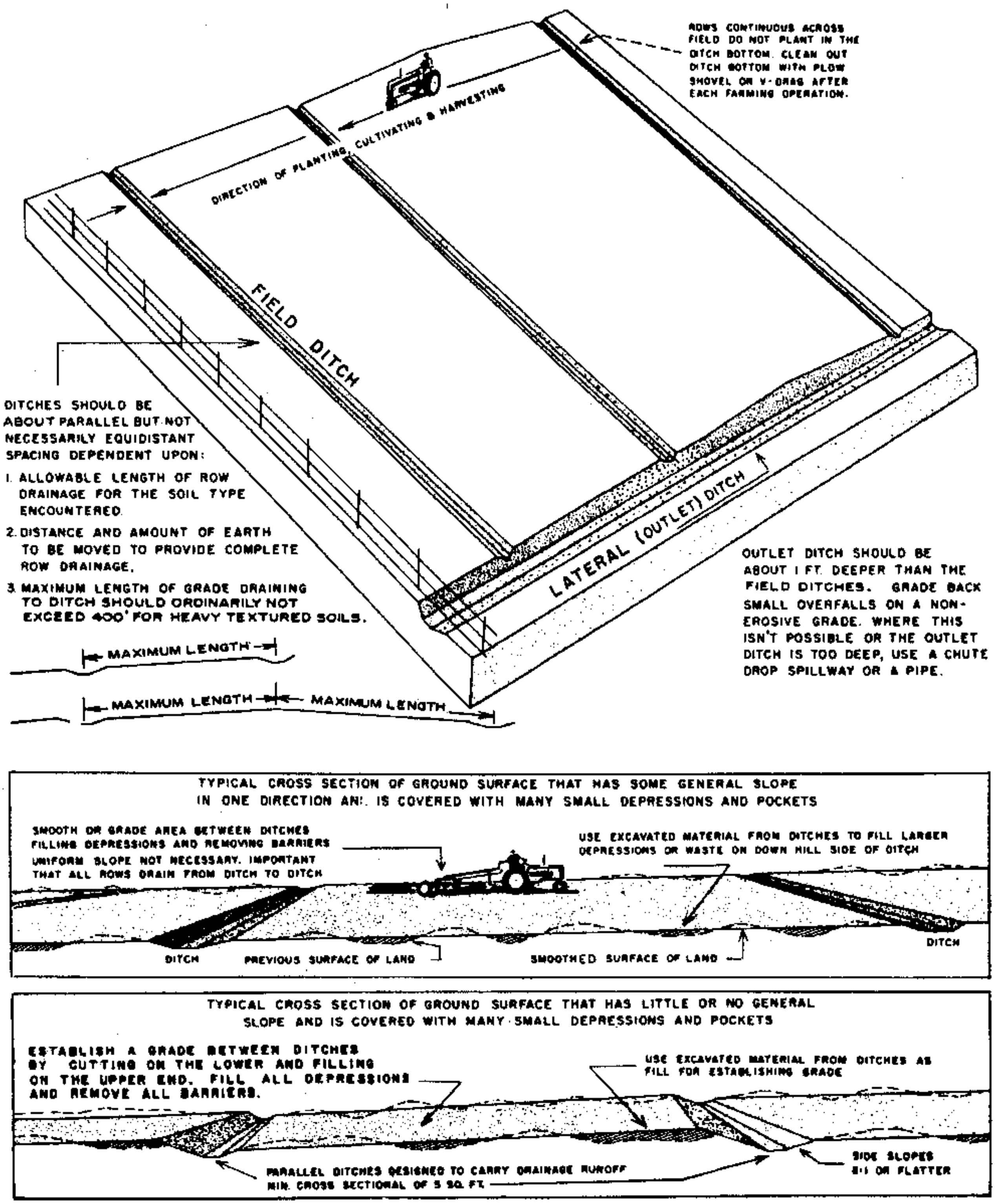


Figure 3 - Parallel ditch system of surface drainage.

d. Plow the field in the direction of greatest slope. Dead furrows should be on a continuous slope to avoid ponding of water.

e. Use land smoothing for maintenance of a continuous grade between collection ditches.

2. Random System

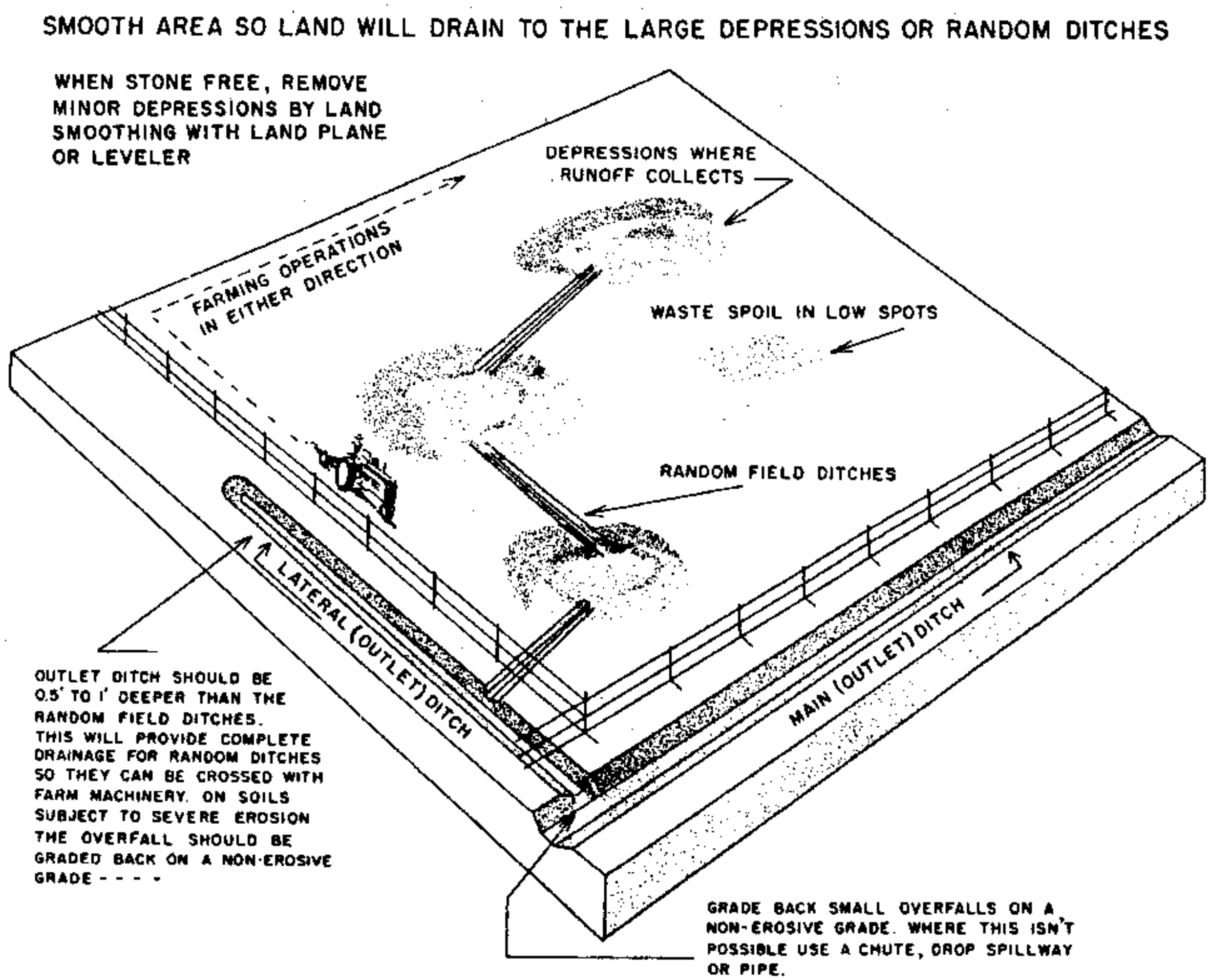
The random system is adapted to slowly permeable soils having depressional areas too large to be eliminated by land smoothing or shaping. These ditches connect the various low spots in a field and provide an outlet to remove the excess surface water. Because of timeliness of removing excess surface water and silting problems, this system is usually preferable to outletting the low spots into a subsurface drain with blind or open inlets.

The channels should follow the natural slope of the land. Spoil from the ditches can be used to fill remaining minor depressions. Land smoothing will improve the effectiveness of random systems. Ponding and siltation may occur where ditch grades are less than .05 foot per 100 feet. Figure 4 illustrates design, layout and construction recommendations for the random ditch system.

3. Cross-Slope (Diversion) System

The cross-slope system resembles terracing in that the ditches go around the slope on a grade according to the lay of the land. In this way they can be used for both drainage and erosion control in sloping, wet fields. This method has application on slopes of 4 percent or less where internal drainage below the 6 to 10 inch depth is poor and where the bottom of the slope remains wet for long periods of time after rains. Collector ditches carry the water downslope at the edge of the field by means of grassed waterways or drop structures. Collector ditches located to one side of the field permit continuous cultivation. Crop rows normally are laid out in the direction of greatest slope where erosion is not a problem.

Ditches in the cross-slope system should be as straight as topography permits with limited cutting through ridges and humps. Spacing for each field should be designed to control erosion losses and permit adequate drainage. Ditch slope should be between .05 and .5 foot per 100 feet, and the



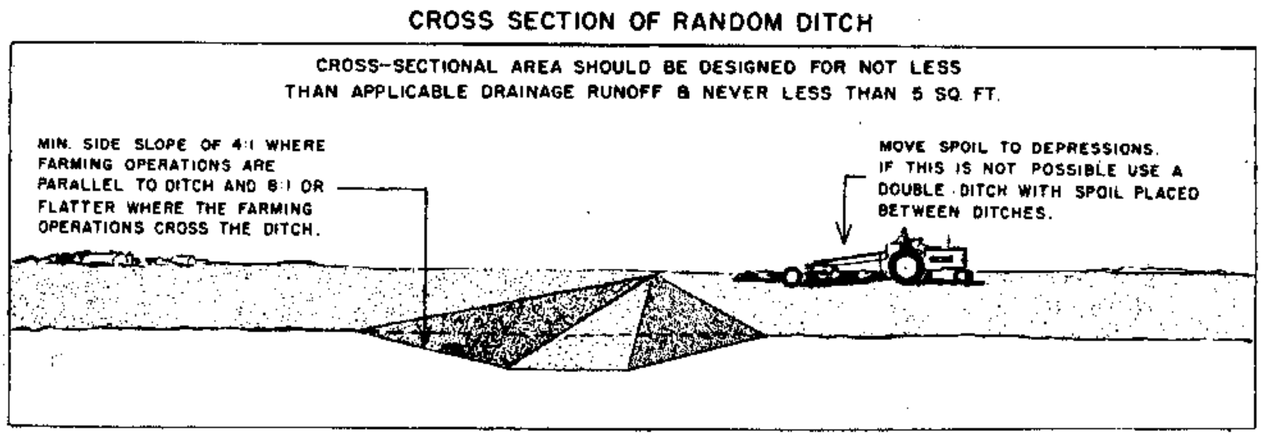


Figure 4 - Random ditch system of surface drainage.

cross-sections should not be less than 6 square feet. A trapezoidal section is recommended, with 8:1 side slopes, a minimum depth of 6 inches, and a minimum bottom width of 6 feet. For a "V" section, use a minimum depth of 9 inches and 10:1 side slopes.

The spoil should be spread over the field and placed in depressions on the slopes between drains. Excess material should be spread no higher than 3 to 6 inches on the downhill side of the ditch. Land smoothing after depressions have been filled will help eliminate all surface basins and humps that obstruct the free flow of surface water between ditches. Figure 5 illustrates additional layout, design and construction recommendations.

Other Surface Drainage Methods

1. Bedding System

The bedding system is adapted to the same soil conditions as the parallel ditch system. Since it is less convenient to farm and usually will not give as complete drainage as the parallel ditch system, this system is not used as extensively today as in the past. It is not usually a desirable system for row crops, since rows adjacent to dead furrows will not drain satisfactorily.

This system is designed, constructed, and maintained so that surface water drains laterally from beds or plow lands into dead furrows and then into collection ditches. Beds should be laid out with the dead furrows running in the direction of greatest slope. Collection ditches can be laid out in the direction of lesser slope, since they can be graded. The collection ditches are usually the key to the effectiveness of a bedding system. Some conditions that affect width of beds are:

a. Slope of the field--flatter fields require narrower beds.

b. Drainage characteristics of the soil--the tighter the soil the narrower the beds.

c. Adaptability to farming operations--the bed width should be a multiple of one round with the plow, planter or cultivator.

d. Kind of crops to be grown.

Figure 6 illustrates the general recommendations on layout of the bedding system.

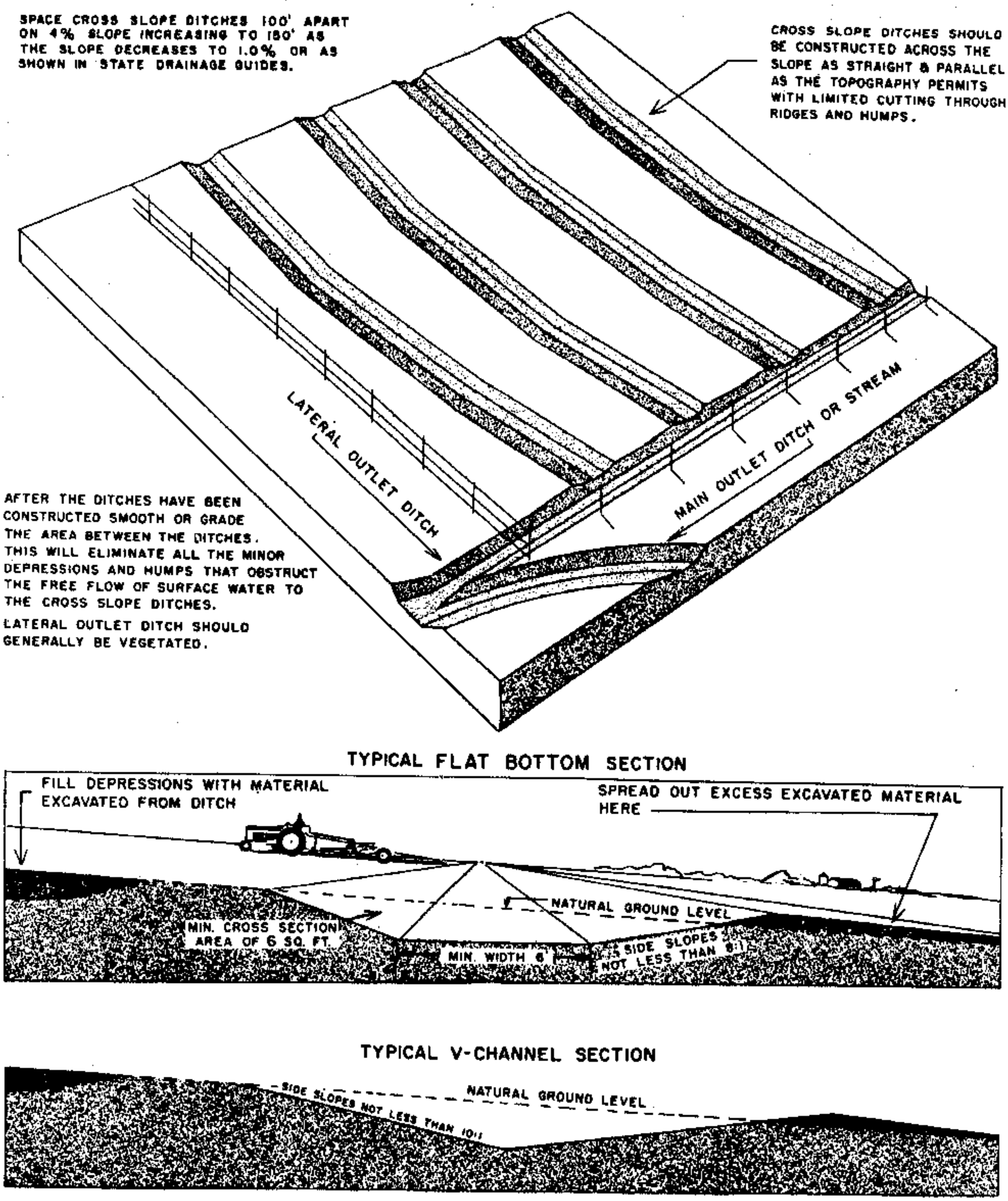
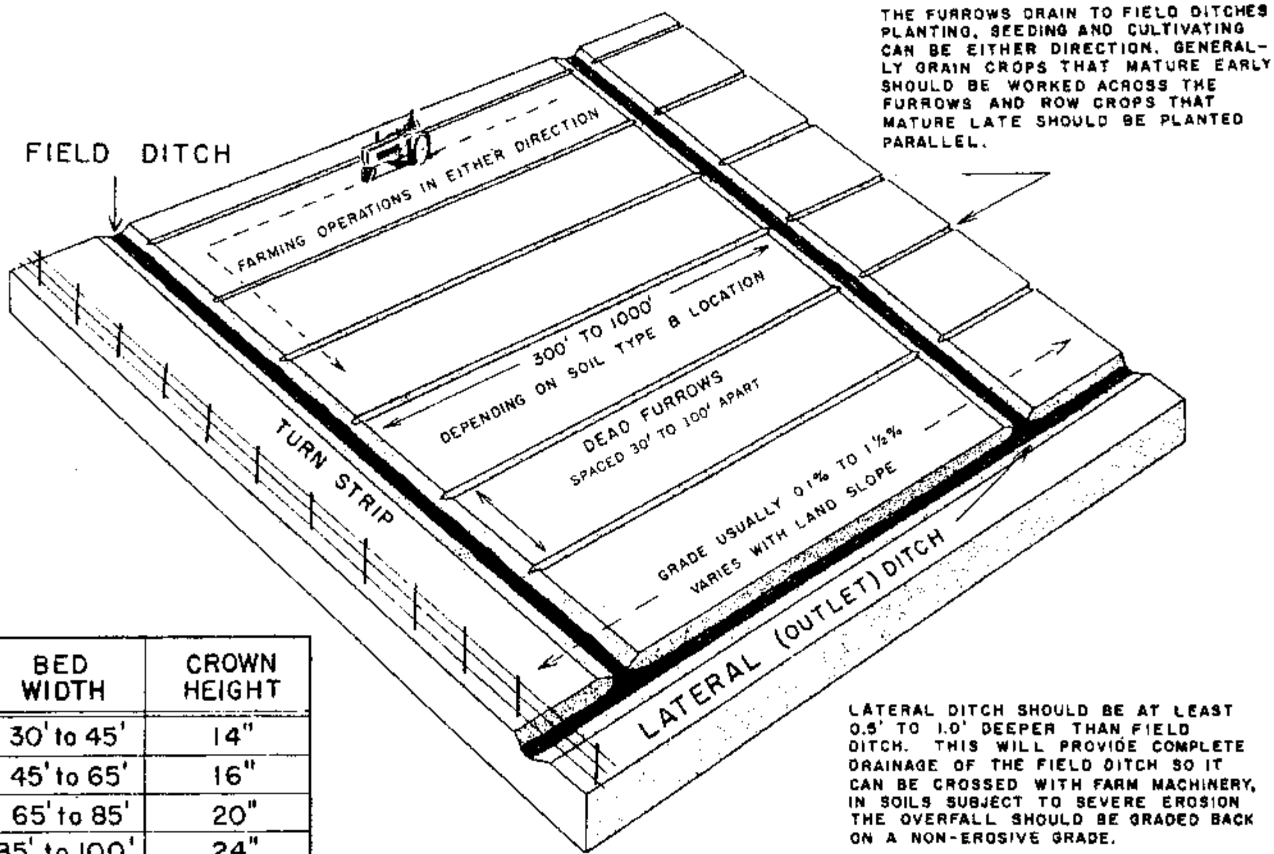


Figure 5 - Cross slope ditch system of surface drainage-terrace type drain



BED WIDTH	CROWN HEIGHT
30' to 45'	14"
45' to 65'	16"
65' to 85'	20"
85' to 100'	24"

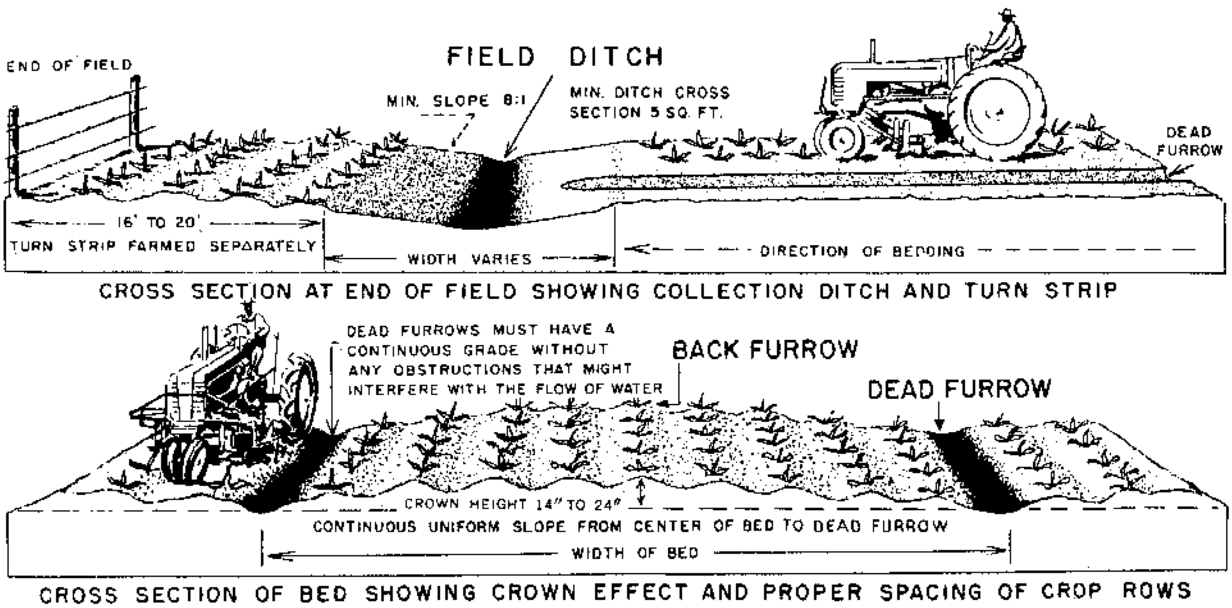


Figure 6 - Surface drainage bedding

2. "W" Ditches

Figure 7 illustrates a general layout of the "W" ditch. The cross section of the "W" ditch system is similar to the single ditch except that, if farm operations will not generally cross the ditches, the side slopes toward the field should be 8 to 1 and those on the island should be 4 to 1. The excavated earth should be shaped into a crowned section between the two ditches of sufficient size to accommodate the spoil which has been removed. The minimum distance between ditch centers should be 30 feet. The grade should not be less than 0.05 percent.

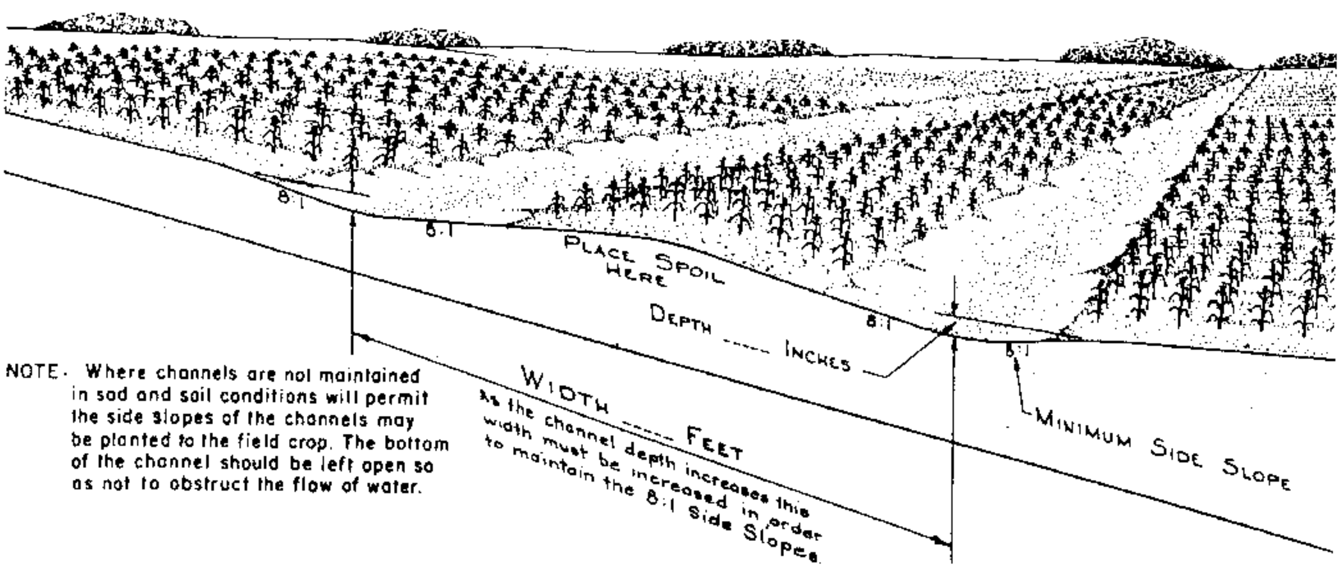
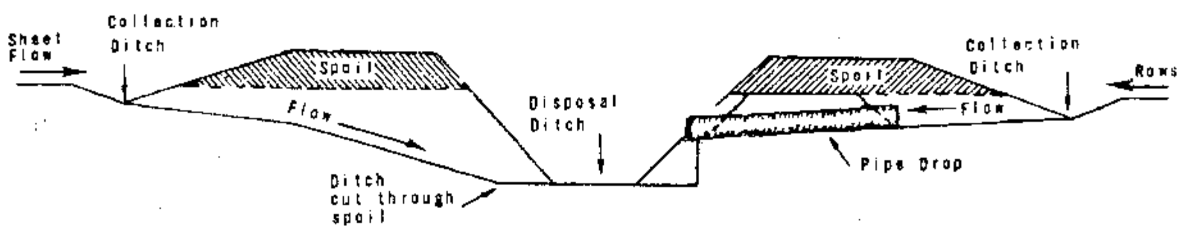


Figure 7 -Layout of the "W" ditch.



Controlled surface water discharge into deep disposal ditch.

Maintenance of Surface Drainage Systems

After a finished grade has been established, it is important that a good maintenance program be adopted. The plowing, planting, cultivating, and harvesting operations often create ridges that disturb the surface enough to impound water. In addition, there may be enough wind and water erosion to provide further disturbance. Therefore, an annual maintenance program should be planned. It is suggested that after each time the field is plowed, a land plane be operated over the area at least twice. One pass should be made along each diagonal. This operation will facilitate settlement in the fill areas and erase all scars on the land surface caused by field operations and, in addition, provide a good seed bed.

SUBSURFACE DRAINAGE

Subsurface drainage is used for soils that are permeable enough for economical spacing of the drains and that are productive enough to justify the investment. A good subsurface drain should provide trouble-free service for many years. These goals require proper installation techniques and the use of quality material.

Location of Subsurface Drainage Systems

An accurate contour map is needed to locate a drain system except where the proper layout can be determined by field examination. Accurate ground profiles along main drains are required. Profiles along laterals may be omitted if the land slope is fairly uniform. The details of the survey to get an efficient layout of the drain system depend to a great extent on topography and the size and complexity of the drainage problem.

Patterns of Subsurface Drainage Systems

To properly plan a subsurface drainage system, a pattern must be selected that fits the topography, location in relation to sources of excess water, and other field conditions. Basic systems that may be selected are illustrated in Figure 8.

Random System

A random system is used where the topography is undulating or rolling and contains isolated wet areas. For efficiency, the main drain is usually placed in the swales rather than in deep cuts through ridges. If the individual wet areas are large, the arrangement of submains and laterals for each area may utilize the gridiron or herringbone patterns to provide the required drainage.

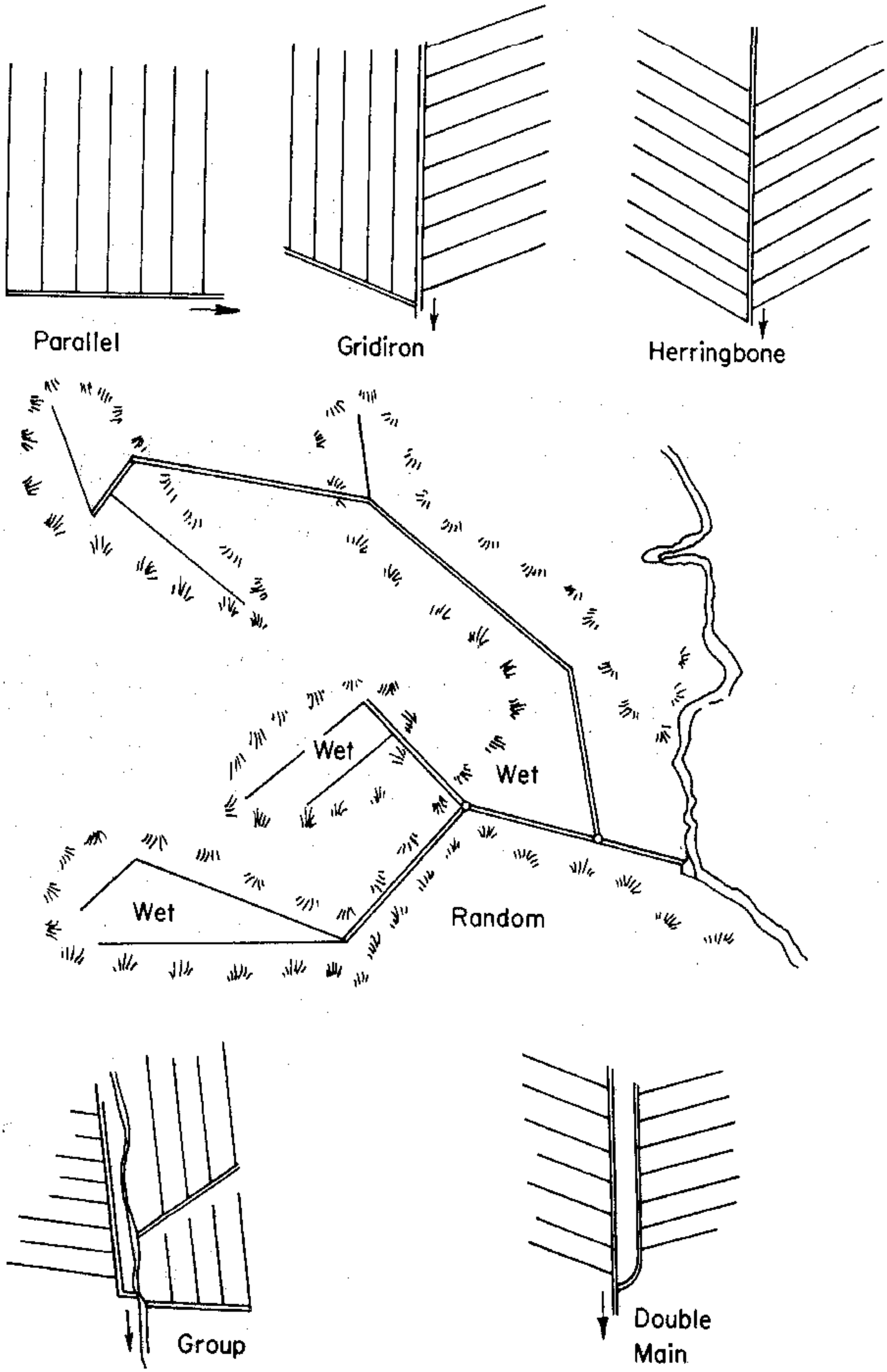


Figure 8 - Types of subsurface drainage systems.

Herringbone System

The herringbone system consists of parallel laterals that enter the main at an angle, usually from both sides. This system is used where the main or submain lies in a narrow depression. It may also be used where the main is located on the major slope and the lateral grade is obtained by angling the lateral upstream. This pattern is used with other patterns in laying out a composite pattern on small or irregular areas. Despite double drainage and added cost of more numerous junctions, herringbone systems are sometime advantageous in providing the extra drainage needed for heavier soils found in narrow depressions.

Parallel or Gridiron System

The parallel or gridiron system is similar to the herringbone system except that the laterals enter the main from only one side. It is used on flat, regularly shaped fields and on uniform soils. Variations of the system are often used with other patterns.

Double-Main System

The double-main system is a modification of the gridiron and herringbone systems and is applicable where a depression, which is frequently a natural watercourse, divides the field where drains are to be installed. Sometimes the depressional area may be wet because of seepage coming from the higher ground. Placing a main on each side of the depression serves a dual purpose; it intercepts the seepage water and it provides an outlet for the laterals. If the depression has depth and is unusually wide and only one main is used in the center, a break in gradeline of each lateral may be necessary before it reaches the main. A main on each side of the depression permits a more uniform lateral grade-line.

Subsurface Drain Outlets

Open ditch or stream outlets should be deep enough and have sufficient capacity to provide a free outlet and adequate cover for all outletting mains and laterals. When a subsurface drain outlets into an open ditch, the end of the drain should always be protected against erosion, damaging periods of submergence, and entry of rodents or other animals into the drain.

Where surface water will not enter the ditch at the location of the drain outlet, a minimum of 10 feet of continuous rigid pipe should be used. At least two-thirds of its length should be embedded into the ditch bank with the overhanging length discharging at the toe of the ditch slope a minimum of 1 foot above the low water flow (see Figure 9). When a placement of a pipe projecting into the ditch will cause a serious ice jam or be damaged by floating ice or debris, the pipe should be recessed into the ditch bank and protected with riprap or turned downstream at approximately a 45° angle with a maximum freeboard of 2 feet.

Where surface water will enter the ditch at the location of the drain outlet, some type of structure is needed to outlet the drain and to safely lower the surface flow to the ditch. When there is no spoil bank, the straight-drop spillway is generally the best type of structure. If there is a spoil bank, and sufficient temporary storage on the land is possible and permissible, a pipe drop-inlet structure will usually provide the best and most economical installation. Sometimes it may be possible to move the drain outlet out of the waterway or divert the surface water to another location at least 60 to 75 feet away and lower the surface flow into the ditch over a sodded chute (see SCS Engineering Field Manual).

Animal guards are needed on all outlets to exclude small animals unless the outlet is so located that it would be impossible for them to enter the drain at the outlet end. Gratings or attached screens should not be used on drain lines that have surface inlets since debris may enter through the inlets and collect on the gratings.

Existing mains that are used as outlets for the proposed subsurface drainage system should be carefully checked to see that they are adequate. To be adequate as an outlet for a new subsurface drainage system, or to accommodate additional laterals, an existing main should:

1. Be free from breakdowns, fractured tile, excessive sedimentation or root clogging.

2. Appear to be working properly and have a free outlet as described above.

3. Have sufficient capacity based on the grade (slope of drain) and degree of drainage required for the area presently drained and for areas to be drained into this main in the future.

4. Have sufficient depth to provide the minimum recommended cover for all new drains to be installed.

Pump outlets may be considered when no suitable gravity outlet is available and it is not practical to improve an existing ditch (see page 47).

Watertight conduits, strong enough to withstand the loads put on them, should be used where subsurface drains cross under waterways or other ditches. Conduits under roadways should be designed to withstand the expected loads and should meet the requirements of the appropriate railroad or highway authority. See Tables XV and XVI. Shallow drains through depressional areas and near outlets should be protected against hazards of farm and other equipment, as well as freezing and thawing.

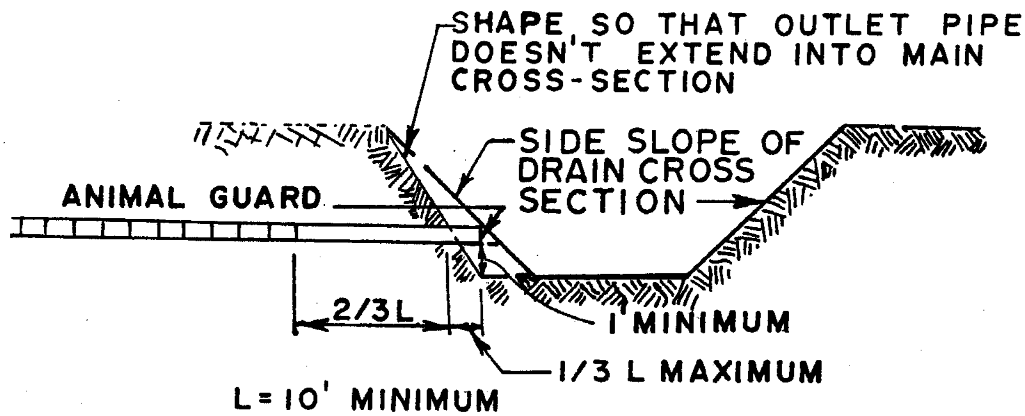


Figure 9. Recessed pipe outlet to open drain.

Minimum Length of Outlet Pipe

Freeboard (Ditch bottom to drain invert)	Drain Size		
	4" & 5"	6" & 8"	10" & Over
Under 2 feet	10 ft.	12 ft.	16 ft.
2 feet and over	10 ft.	16 ft.	20 ft.

MATERIALS FOR SUBSURFACE DRAINAGE

Materials used for subsurface drainage include conduits of clay, concrete, bituminized fiber, metal, plastic, or other materials of acceptable quality. The conduit should meet strength and durability requirements of the site. Current specifications, as listed in Table XIII in the Appendix, or as included in Ohio Standards and Specifications for Conservation Practices prepared by the Soil Conservation Service, or Federal specifications, should be used in determining the quality of the conduit.

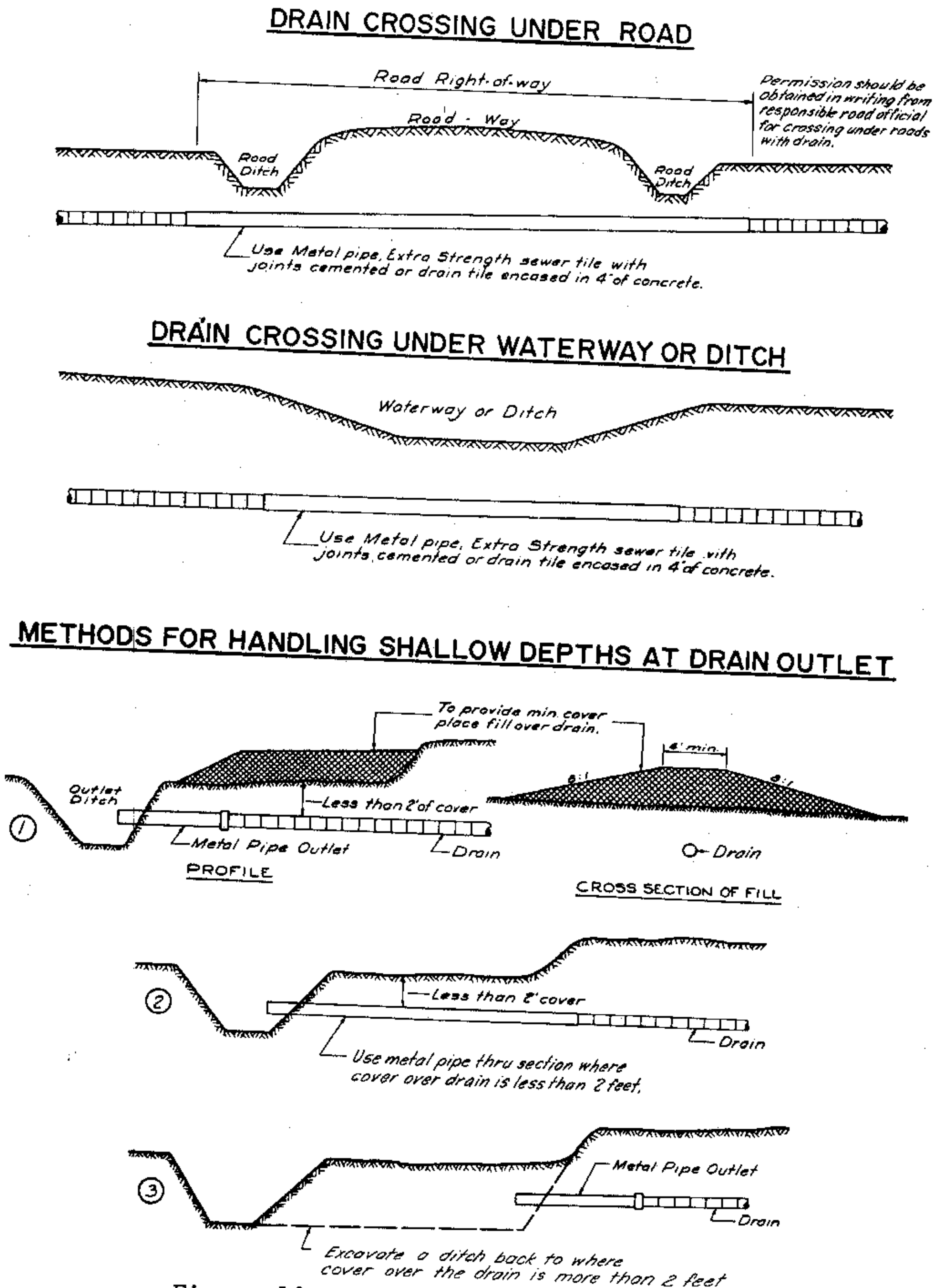


Figure 10 - Drain crossings and outlet.

The following specifications cover the products currently acceptable for use as drains or for use in determining quality of materials used in drainage installations.

Three classes of concrete drain tile are recognized. These are standard quality, extra quality, and special quality. Also, there are three classes of clay drain tile. These are standard quality, extra quality, and heavy duty. In choosing the quality to use, general recommendations are:

1. Standard quality drain tile may be used when laid with at least 2 feet of cover and in trenches of moderate depth and width. (See Tables XIII and XIV in Appendix)

2. Extra quality, special quality, or heavy duty drain tile should be specified for unusual conditions of exposure or where tile are laid in trenches of considerable depth, width or both. (See Tables XIII and XVI in Appendix.)

Concrete drain tile should be properly cured before installing. This means that air-cured concrete drain tile should not be installed until 28 days after manufacture. Steam-cured concrete tile approach ultimate strength in about 3 or 4 days. Concrete tile should not be removed from the manufacturing plant until cured to meet ASTM specifications.

Some clay or shale drain tile may be damaged by frost. They should not be "strung out" or stacked on wet ground during periods of freezing and thawing. Drain tile stored on the farm or at the supplier for several years prior to installation should be carefully examined for damage.

Soil acids affect concrete tile to a varying degree depending on the soil acidity and the tile quality. Clay tile are not affected. The degree of soil acidity is commonly expressed by pH values. A pH value of 7.0 is neutral. When the pH number is greater than 7.0, the soil is alkaline. Conversely, when the pH number is less than 7.0, the soil is acid, and the smaller the number, the greater the acidity. The use of concrete tile under acid conditions should be in accord with Table XIV in Appendix.

Most plastic tubing is made from high density polyethylene resin. Two of its characteristics are flexibility, which permits coiling, and light weight in comparison to clay and concrete drain tile. Corrugated plastic tubing for subsurface drainage should have the following characteristics:

1. Sufficient strength to withstand the soil load without collapse, buckling, or compression of the side walls.

Unlike rigid clay or concrete tile, the strength increases with deflection up to the point where failure begins. To be meaningful, strength must be related to deflection.

2. Sufficient toughness or lack of brittleness so that it will not crack on impact or develop stress cracks when loaded for a long period of time.

3. Durable when exposed to sunlight for extended periods and to chemicals normally present in soils. (Polyethylene tubing should be made only from virgin resin material.)

4. Adequate openings uniformly distributed along and around the tubing and placed so as not to cause an appreciable loss in strength.

5. Relatively smooth on the inside and free from defects, burrs, and projections.

6. Uniform in wall thickness and strength, and circular in shape.

ASTM specifications are currently being developed.

Drainage Coefficient for Subsurface Drainage

The drainage coefficient is the rate (in inches per 24 hours) that water must be removed from the drained area to provide the required protection for the crops being grown. The frequency, intensity, and duration of rainfall, the porosity and permeability of the soil, and the kind of crop grown should be considered in selecting the drainage coefficient.

When the land to be drained has good surface drainage, either from natural topography or from an installed surface drainage system, and no surface water is admitted directly into the subsurface drainage system, the coefficients in Table IV should be used.

Where surface water enters the drain system through surface inlets, the coefficients in Table V should be used.

When high-value truck crops might be damaged by standing in water for 2 to 4 hours during hot weather, higher coefficients than those given in Table IV may be necessary to reduce crop damage.

Table IV. Drainage Coefficients for Subsurface Drainage Only

Soil	Coefficient (inches to be removed in 24 hours	
	Field Crops	Truck Crops
Mineral	3/8 to 1/2	1/2 to 3/4
Organic	1/2 to 3/4	3/4 to 1-1/2

Table V. Drainage Coefficients Where Surface Water Enters Subsurface Drains

Soils	Coefficient			
	Drainage Field Crops		Drainage Truck Crops	
	Blind Inlets	Open Inlets	Blind Inlets	Open Inlets
Mineral	1/2 to 3/4	1/2 to 1	3/4 to 1	1 to 1-1/2
Organic	1/2 to 1	1/2 to 1-1/2	3/4 to 2	2 to 4

When a drain is used to intercept seepage or springs, adequate field investigations must be made to determine the amount of seepage as well as the watershed area contributing to the seepage problem and the time required for the seepage to reach the drain. Seep planes are first located by soil borings, with hand augers, or with excavating equipment. The drain is then located so that continuous interception of such seep planes, adequate soil cover over the drain, and grade to an available outlet are established. Interception drains are installed at approximately right angle to the flow of ground water to intercept subsurface flows. Where there are watercourses, a layout may consist of a main or submain drain located on one side of the watercourse, with the interceptor lines located across the slope.

Table VI. can be used as a guide to determine the required capacity of single random intercepting lines.

Table VI - Inflow Rates for Interceptor Lines

Soil texture	Inflow rate per 1,000 feet of line in c.f.s.1/,2/
Coarse sand and gravel	.15 to 1.00
Sandy loam	.07 to .25
Silt loam	.04 to .10
Clay and clay loam	.02 to .20

1/ Discharge of flowing springs or direct entry of surface flow through a surface inlet or filter must be added. Such flow should be measured or estimated.

2/ Required inflow rates for interceptor lines on sloping land should be increased by 10 percent for slopes 2 to 5 percent, by 20 percent for slopes 5 to 12 percent, and 30 percent for slopes over 12 percent.

The size of the interceptor drain for a particular set of conditions can be determined by using Table VI and Figures 19, 20 or 21 in the Appendix. Table VI provides inflow rates for different soil textures. Find the total desired inflow for the drain line on the right side of Figure 19, 20 or 21. Move horizontally to the left until you intersect the grade or slope of the line. This point locates the size of drain required.

Subsurface Drain Sizes

Mains should be large enough to drain all areas in the watershed needing drainage, using the appropriate drainage coefficient. They should have a free outlet and be deep enough to provide outlets for all laterals to be installed. There are several types of lateral systems that can be used as noted (see Figure 8). A system should be selected that will fit the needs of the area being drained. For depth and spacing of laterals in various soil types, see Table II.

Drain size is determined by referring to Table XII for capacity needed for appropriate drainage coefficient. Using the cfs value from Table XII use Figure 19, 20 or 21, as appropriate. Enter the chart on the right side then move horizontally to the left until you intersect the grade or slope of the line. This point determines the size of the drain and also the flow velocity in the drain when it is flowing full.

The minimum recommended sizes are: 4-inch-diameter drains for short laterals in mineral soils (other than sandy or organic soils); 5-inch drains for sandy soils and for organic soils with short laterals; 6-inch drains (a minimum of 2 feet long) for organic soils.

Minimum size for main lines is normally 5 inches. For subsurface drains exceeding 10 inches in diameter, it is preferable to use 2-foot or longer lengths to maintain alignment.

Subsurface Drain Grades

Subsurface drains are placed at rather uniform depths. Therefore, the topography of the land may dictate the range of grades available. There is an opportunity, however, to make some grade selections by altering the location of the drains. The selection of grades should, if possible, be sufficient to develop a velocity of at least 1.4 feet per second to prevent sediment accumulation in the drain. Otherwise, precautions should be made for prevention of sedimentation by the use of filters or by the collection and removal of sediment with sediment traps. The velocity should not be great enough to cause turbulence and undermining of the drain.

Where sediment is not a hazard, drains can be installed on minimum grades as indicated in Table VII.

Table VII. Minimum Grades for Drain Lines

Drain size (inches)	Minimum grade (percent)
4	0.10
5	0.07
6 or more	0.05

On sites where topographic conditions require the use of drains on grades that produce velocities greater than those shown in Table VIII, special construction practices should be used to protect the line.

Table VIII. Maximum Permissible Velocity in Drains Without Protective Measures (non-pressure flow)

Soil texture	Velocity (feet per second)
Sand and sandy loam	3.5
Silt and silt loam	5.0
Silty clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

Subsurface Drain Depth

Minimum cover over the drains should be 2 feet in mineral soils and 2-1/2 feet in organic soils measured from the top of the drain to the surface of the ground. Less cover may be used for short distances near the outlet, where they cross under highway or railroad ditches, or in small pothole areas. However, additional protection, such as a long length of rigid drain pipe should be used, or fill should be placed over a drain line as noted in Figure 10. Minimum cover for corrugated plastic drain tubing should be as follows:

4 - 6 inch diameter - 24" cover
8 - 12 inch diameter - 30" cover

Maximum depth for clay and concrete drain tile depends on tile quality and trench width. Depths should not exceed those given in Table XVI in Appendix. Also, see Table XV in Appendix concerning wheel loads. Flexible drains, properly installed will withstand greater trench depths than rigid drains. Therefore, the same depths and widths can be applied to both with safety.

Horizontal Alignment

Changes in horizontal direction of drain lines may be made in several different ways. A gradual curve of the trench may be made on radius that the trenching machine can dig and maintain the specified slope. A gradual curve may be made by shaping the inside of the curve by hand and chipping the tile, where clay or concrete drain tile are used. However, in no case should the radius of curvature be less than 5 feet. Manufactured bends or fittings are recommended to change direction. Junction boxes or manholes may be used where drain lines make an abrupt change in direction or where two or more large drains join.

Junction Boxes

Junction boxes may be used where more than two mains or laterals join. Junction boxes are especially needed if mains join at different elevations.

Wherever possible, junction boxes should be located in permanent fence lines or in areas not in cultivation. The cover should be above ground for easy inspection and cleanout. The bottom of the box should not be less than 1 foot below the flow line of the outletting drain. This depth should be increased when a junction box also serves as a sediment trap.

If the junction box is placed in a field, and it is necessary to cultivate over it, the top should be at least 18 inches below ground surface. A strong cover should be provided and the location carefully recorded on the drain location map so it can be easily found. See Figure 11 for a typical junction box design.

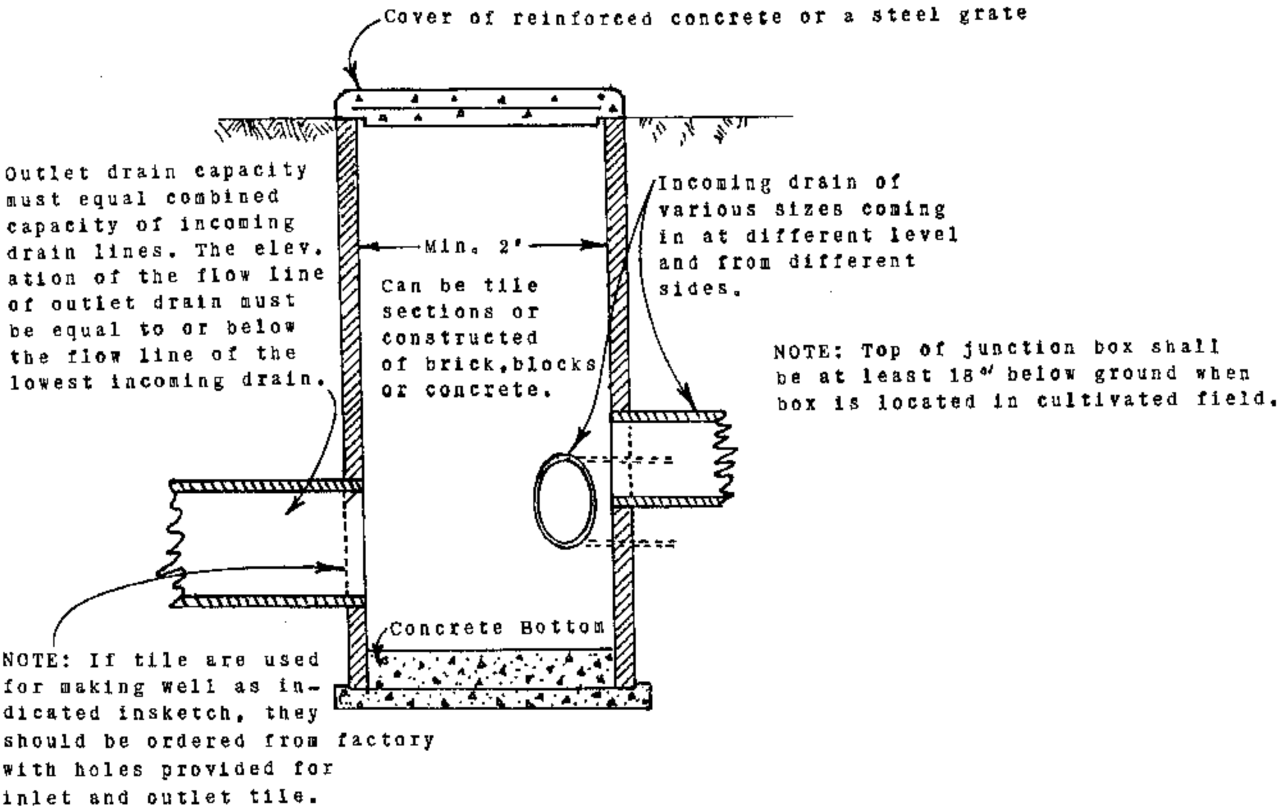


Figure 11 Junction box for drain lines.

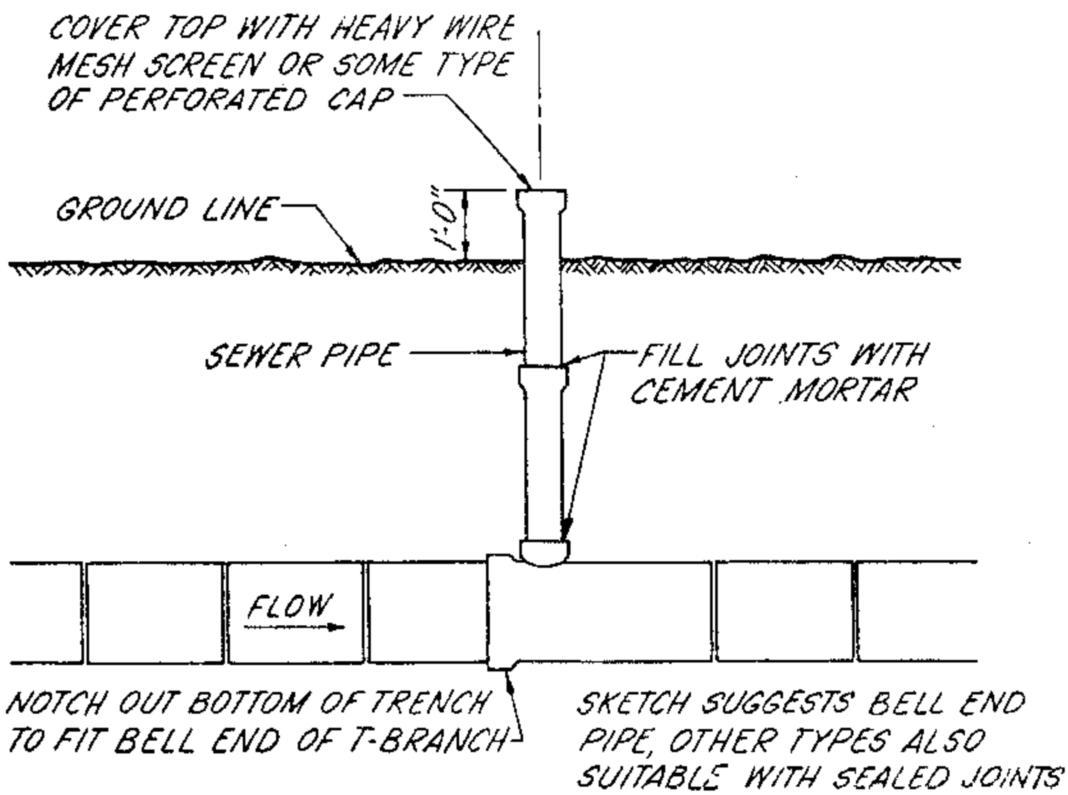


Figure 12 - Relief well.

Relief Wells

Relief wells relieve pressure in the line that might otherwise cause the drain to blow out. Relief wells are constructed by placing a "T" connection in the line and cementing sewer pipe or similar pipe vertically into the "T" (see Figure 12). The pipe should extend about 1 foot above the ground surface unless it will also be used as a surface inlet. The exposed end of the pipe should be covered with heavy wire mesh or some suitable grating to keep debris out of the drain line. The riser of the relief well should have a minimum diameter of 6 inches.

Relief wells should be located where the drain line might become over-loaded for short periods of time, or when full flow changes to partial flow due to increasing grade. Relief wells are also needed on lines that have surface inlets, particularly downstream from large inlets.

Surface Inlets

Open surface inlets should be used with caution and be carefully constructed. A sediment or silt trap should be an integral part of any open inlet that admits an appreciable amount of water and/or sediment into the drain line. For small amounts of water admitted through a surface water intake, the drain line should be replaced with sections of rigid pipe, tubing or drains with sealed joints on each side of the inlet riser. The inlet should be protected with a dome-like grating, sometimes called a "beehive" grate, or a vertical section of pipe with holes to keep trash or weeds from clogging the drain. Narrow-spaced horizontal grates or wire mesh clog very easily and therefore are not recommended. See Figures 13, 14 and 15.

Blind inlets (French drains) may be used if the quantity of surface water is not large. They are used mostly on lateral and random lines. The blind inlet will become clogged with silt in time. The frequency of clogging will depend upon the amount of silt carried into the filter by surface water.

When the inlet fails to work properly, it should be cleaned or a new inlet constructed adjacent to the old one.

To clean an inlet remove the filter material from the trench, then remove the silt from the filter material and replace the filter material in the trench.

A blind inlet may be constructed by backfilling a short section of the drain line with stone or gravel. Blind inlets should be placed in the lowest part of the depression through which the drain passes. See Figure 16. Refer to Table V for drainage coefficients with surface inlets.

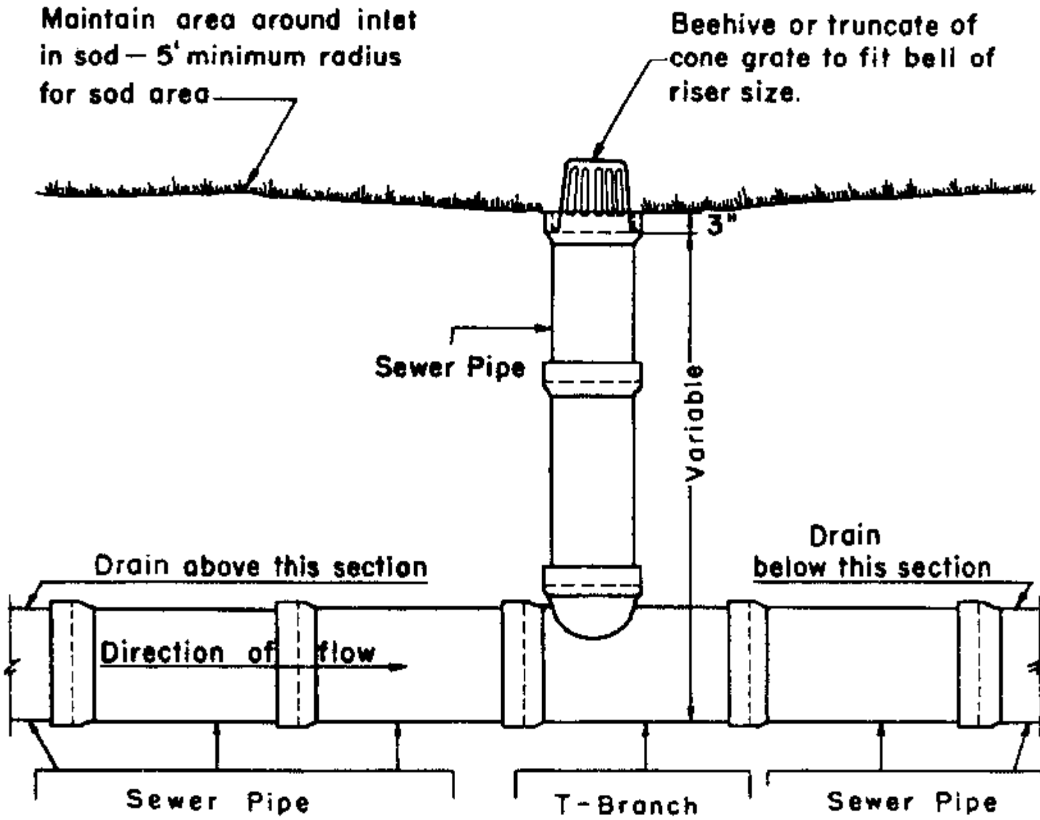


Figure 13 - Open surface inlet for small drainage areas.

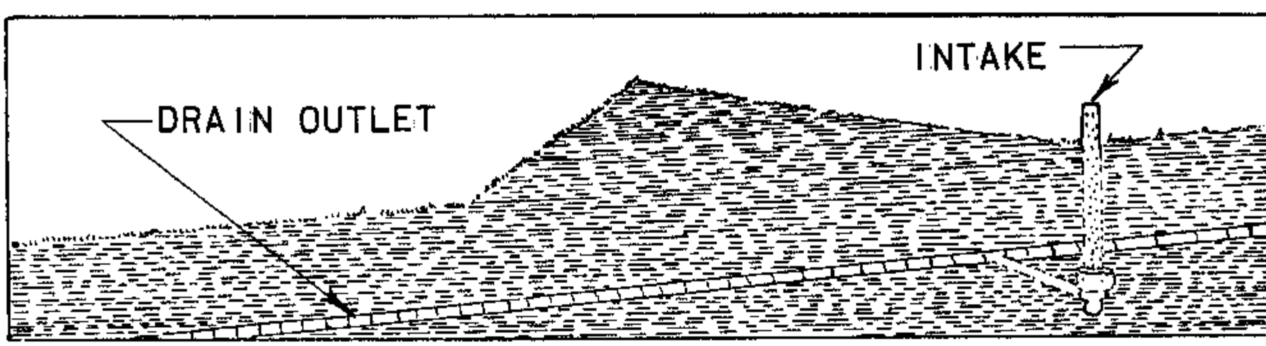


Figure 14 - Cross-sectional view of Terraces using perforated pipe intake with underground outlet.

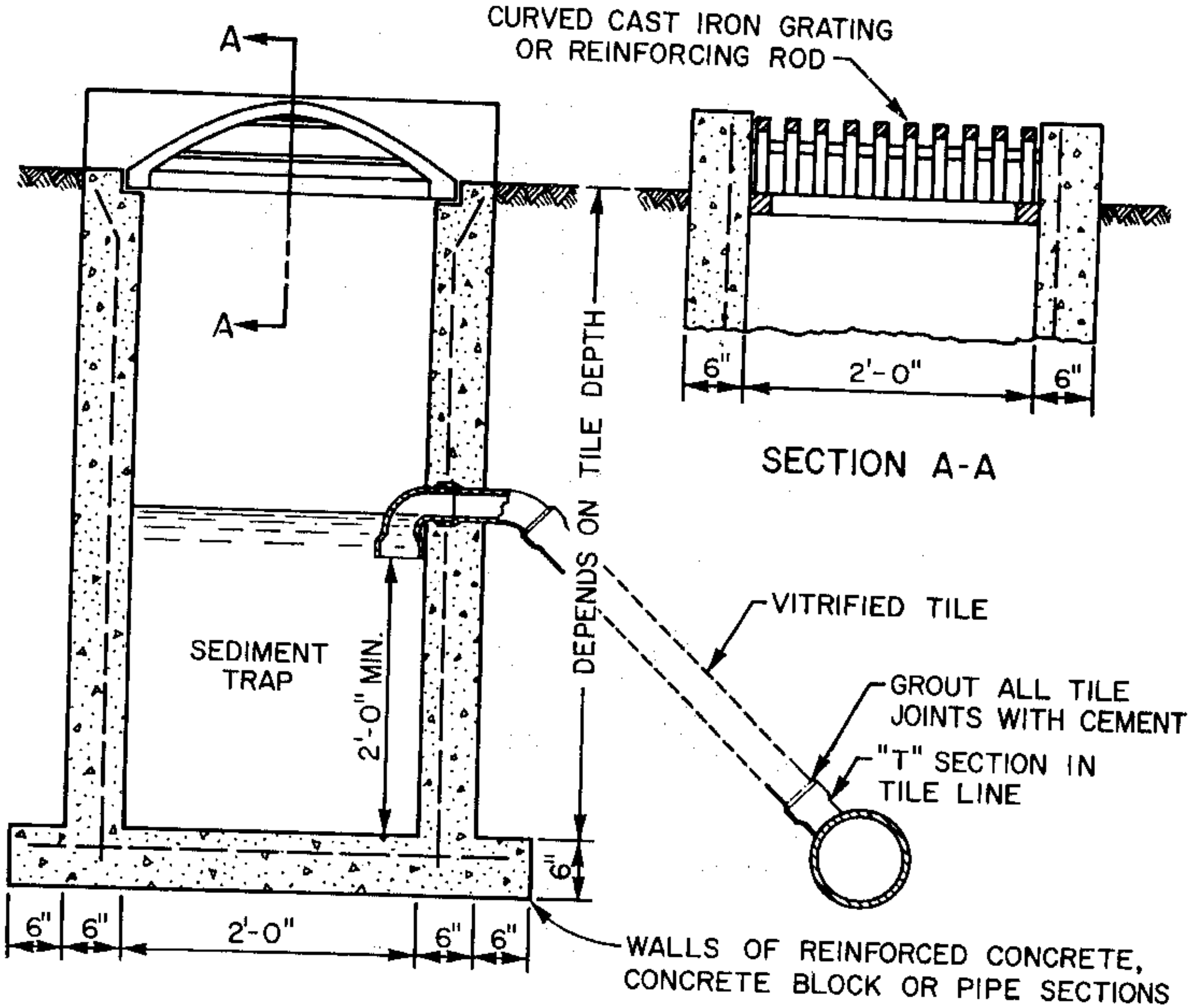


Figure 15 - Open surface inlet with sediment trap.

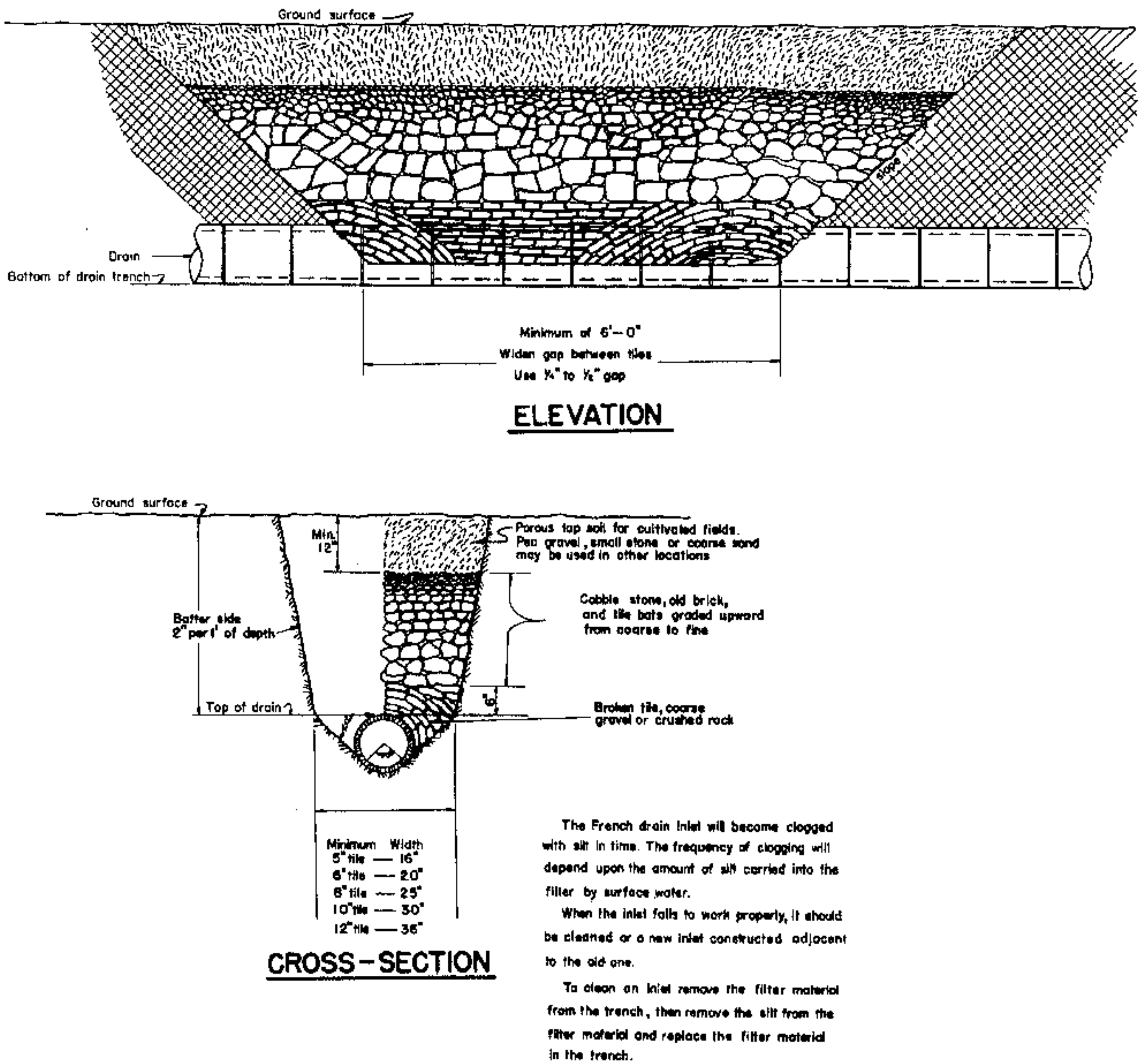


Figure 16 - Blind surface inlet.

ENVELOPES

Envelopes should be used around drains where required to improve the flow of groundwater into the drain, and/or to provide lateral support for the flexible drain. See Table IX.

Materials used for envelopes do not need to meet the graduation requirement of filters, but they should not contain materials which will cause an accumulation of sediment in the drain or render the envelope unsuitable for bedding of the conduit. The envelope materials should fill the trench to a minimum of three (3) inches over the top of the drain. Envelope material should consist of sand-gravel material, all of which should pass a 1-1/2 inch sieve, 90 to 100 percent should pass the 3/4 inch sieve, and not more than 10 percent should pass the No. 60 sieve.

FILTERS AND SCREENS

Suitable filters or screens should be used around drains where required by site conditions to prevent sediment accumulation in the drain. The need for a filter or screen should be determined by the characteristics of the soil materials at drain depth and the velocity of flow in the drain. See Table IX.

No less than three (3) inches of filter material should be used for sand-gravel filters. A recommended method of installation is to place filter material to a depth of three (3) inches under the drain, and cover the drain and filter with a sheet of plastic. The filter should be designed to prevent the material in which the installation is made from entering the drain. Not more than 10 percent of the filter should pass the No. 60 sieve.

When fiberglass, spunbound nylon, or other suitable filter or screening materials are used, the manufacturer of the material should certify that it is suitable for underground use. The materials should cover all open joints and perforations.

Subsurface Drain Installation

Grade stakes to govern alignment and grade should be set approximately every 100 feet. Targets should always be used as a guide to keep the trench bottom to exact grade on all drain line construction. At least three targets should be set along any given strip of continuous grade. Key targets should be set at 500- to 700-foot intervals, or at points of change in grade. Intermediate targets may be set in correct position by carefully sighting between key targets. After setting, each target should be checked for depth of cut as indicated by its respective grade stake. Where automatic depth and grade control systems are used, stakes are needed only for alignment.

A CLASSIFICATION TO DETERMINE THE NEED FOR DRAIN FILTERS OR ENVELOPES, AND MINIMUM VELOCITIES IN DRAINS				
Unified Soil Classification	**Soil Description**	**Filter Recommendation**	**Envelope Recommendation**	**Recommendations for Minimum Drain Velocity**
SP (fine) SM (fine) ML MH	Poorly graded sands, gravelly sands. Silty sands, poorly graded sand-silt mixture. Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity. Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Filter needed	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	None
GP SC GM SM (coarse)	Poorly graded gravels, gravel-sand mixtures, little or no fines. Clayey sands, poorly graded sand-clay mixtures. Silty gravels, poorly graded gravel-sand silt mixtures. Silty sands, poorly graded sand-silt mixtures.	Subject to local on-site determination.	Not needed where sand and gravel filter is used but may be needed with flexible drain tubing and other type filters.	With filter - none. Without filter - 1.40 feet/second.
GC CL SP,GP(coarse) GW SW CH OL OH Pt	Clayey gravels, poorly graded gravel-sand-clay mixtures Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. Same as SP & GP above. Well graded gravels, gravel-sand mixtures, little or no fines. Well graded sands, gravelly sands, little or no fines. Inorganic, fat clays Organic silts and organic silt-clays of low plasticity. Organic clays of medium to high plasticity. Peat	None	Optional. May be needed with flexible drain tubing.	None - for soils with little or no fines. 1.40 feet/second for soils with appreciable fines.

Table IX. Need for drain filters or envelopes.

Starting point for trenching should always be at the outlet with progress upstream. Trench alignment on straight lines should be excavated true to the lines as staked. On curves the trench should be excavated on a true curve and not on chords with sharp turns at the stakes. Drains should be laid true to line and grade and firmly embedded in the bottom of the trench. The drain should be kept laid to within a few feet of the finished trench. For flexible drain tubing, the bottom of the trench should be rounded so the drain can be embedded in undisturbed soil for 120 degrees (1/3 of their circumference). For rigid drain a trench groove is desirable to keep drain in alignment.

The constructed grade must allow the drain to provide the capacity required to drain the area. A reverse grade should not be permitted in drain lines. Correction for overdigging may be accomplished by filling with either well-graded gravel or well-pulverized soil. Soil must be tamped to the approximate density of the original soil condition to provide a firm foundation. The bottom of the trench must again be graded and shaped to the desired grade.

All junctions should be made with standard manufactured fittings, if possible. If manufactured fittings are not available, junctions should be carefully made and sealed with mortar which should be allowed to harden before backfilling. Junctions should be made so that the center of the lateral is not lower than the center of the main. When laterals are much above the main they should be gradually lowered to enter the main at or near the center.

Clay or Concrete Drain Tile

The joints should have a 1/8-inch gap or opening, except in sandy or muck soil. In sandy soil, the closest fit possible should be obtained. In peat and muck, it may be desirable to increase the space between tile slightly more than 1/8 inch. Cradling with planks or use of a stabilizing mat, may be necessary to preserve grade and alignment of tile in some peat, muck, and sand. Where the distance through unstable sand, peat, or muck is appreciable, the use of long sections of rigid perforated pipe designed for agricultural drainage should be considered. All drains shall be laid to line and grade and covered with approved blinding, envelope, or filter material to a depth of not less than three (3) inches over the top of the drain.

Corrugated Plastic Drain Tubing

The tubing should be embedded in undisturbed soil for approximately 120 degrees of its circumference. Friable material taken from the trench spoil or cut from the trench side wall should be placed around and over the drain to a depth of at least three (3) inches above the top of the tubing. To be suitable, materials surrounding the drain must contain no hard clods, rocks or fine materials which would cause a sediment hazard in the drain. When special shaping or grooving of the trench bottom is not provided, the tubing should be laid directly upon the flat trench bottom and covered with gravel envelope material to a depth of at least three (3) inches above the top of the tubing. The tubing should not be stretched more than 5 percent during installation, since stretching results in lower tubing strength. Particular care should be taken to avoid excessive stretch in hot weather. The strength of plastic tubing is reduced about 40 percent when its temperature rises from 70° to 100°F. Tubing strength increases about 70 percent when its temperature is lowered from 70°F to 35°F. However, rapid uncoiling of tubing at very low temperatures may result in excessive stresses and cracking.

As soon as the drains are placed they should be blinded by covering them with soil to a depth of 3 to 6 inches. Where filter or envelope materials are used, all openings into the drain should be covered by the material. See sections on envelopes, filters and screens on page 43. Unfinished lines should be blocked at the end of a day's run to keep earth debris and rodents out of the line. The upper end of each drain line should be capped with durable material.

Backfilling the trench should be completed as rapidly as is consistent with progress of the work and should always be done before backfill material freezes, however, it should be a gradual process. After backfilling, all excess soil shall be placed over the trench to allow for settlement.

Trees such as willow, elm, soft maple, cottonwood, and other water-loving trees within approximately 100 feet of the drain should be removed. A clearance of 50 feet should be maintained from other species of trees. If it is not possible to remove the trees or reroute the line, a closed line with rootproof joints should be constructed. This closed line should extend throughout the root zone area.

A plan should be prepared by the designer for each drain installation. This plan will be used by the contractor during construction and should be kept by the landowner as a record. It is desirable that a final location map or aerial photo of the subsurface drainage system be filed with the abstract for the tract of land drained. The location map will be quite valuable when planning and installing additional drains later.

Maintenance of Subsurface Drainage Systems

A broken or clogged drain can cause an entire system to fail. A "blow hole" or "sink hole" can block the line with earth if not promptly repaired. Surface inlets should be kept open at all times. They should be inspected annually, after major storms, and repaired where needed. If erosion occurs at an outlet, it should be promptly corrected.

PUMP DRAINAGE

Drainage pumping plants may be used to remove excess surface or groundwater from lowlands if it is impossible or uneconomical to obtain gravity outlets for drainage (see Figures 17 and 18). Pumping plants are also used at locations that have adequate outlets except during periods of prolonged high water.

When a drainage problem may involve gravity drainage or pump drainage, or a combination of the two, the economics of all alternate solutions should be determined. The pumping plant or any needed dikes should be planned and designed as an integral part of the drainage system. The reconnaissance or preliminary survey will determine the condition of the drainage outlet and whether pumping is required. A drainage system where the pumping plant is designed into the system usually will function much more efficiently than one where the pumping facilities are added because the outlet is found to be inadequate after the system is installed.

The pumping plant must be designed to pump the amount of water necessary to give adequate drainage against the total head expected. In determining this, consideration should be given to disposing of all the runoff water possible by diversion around the area and to providing for all possible gravity flow through floodgates.

The plant should be located to best serve the purposes while considering such plant requirements as foundation conditions, the need for access for servicing, proximity to sources of power, and locations that might be susceptible to vandalism. In those areas where significant sump storage is available, the pumping plant should be located to take maximum advantage of the storage provided. The location should be one that will permit safe discharge into the outlet.

If possible, the plant should be located in an easily accessible place. Ordinarily the dike can be widened to accommodate vehicular traffic to the plant. It is desirable to have an all-weather access road. Borings should be made and the location selected that has the best foundation conditions consistent with other site requirements. An unstable foundation can increase the cost of a pumping plant considerably. A more intensive investigation before selecting the plant location will often yield big dividends in reduced costs of providing a stable foundation.

Types of Pumps and Pump Drives

Pumps used for pump drainage are of the high-volume, low-head class. This class includes the axial-flow propeller pumps and certain types of centrifugal pumps. For areas smaller than five acres, commercial sump or marine bilge pumps can be used. Pumping volumes and heads must be determined carefully, since friction factors become critical at settings other than those recommended by the manufacturer.

Electric power has the advantage of permitting automatic operation and elimination of the need for daily fueling or servicing activities. Usually, a 10-horsepower motor is the largest that can be used on single phase 230-volt lines. Larger motors can be operated where three-phase power is available or where phase converters can be used on single phase power lines. Where electric power is planned, the power supplier should be consulted for suggestions and recommendations on the most feasible arrangement. If electric power is not available, diesel, gasoline, or L-P gas stationary power units can be used to operate the pump. A farm tractor, with belt or power takeoff drive, may be used to operate the drainage pump in an emergency.

Operation and Cycling

Although pumping may be cyclic in design, electric motors (if used as pump motors) should have continuous load ratings to take care of sustained inflows. Electric motor operation can be easily controlled by automatic switches. Internal combustion engines will require manual control for set periods or some means of throttle or clutch control to make them automatic. Automatic safety cutouts will eliminate the need for an operator during most of the period that the engine is running. Safety cutouts (engine temperature, engine oil pressure, and pump pressure) should be attached to any engine if it is to be left running unattended.

Detailed information on the design of drainage pumping plants is available in Chapter 7 of the SCS publication "Drainage of Agricultural Land" (Sec. 16, SCS National Engineering Handbook).

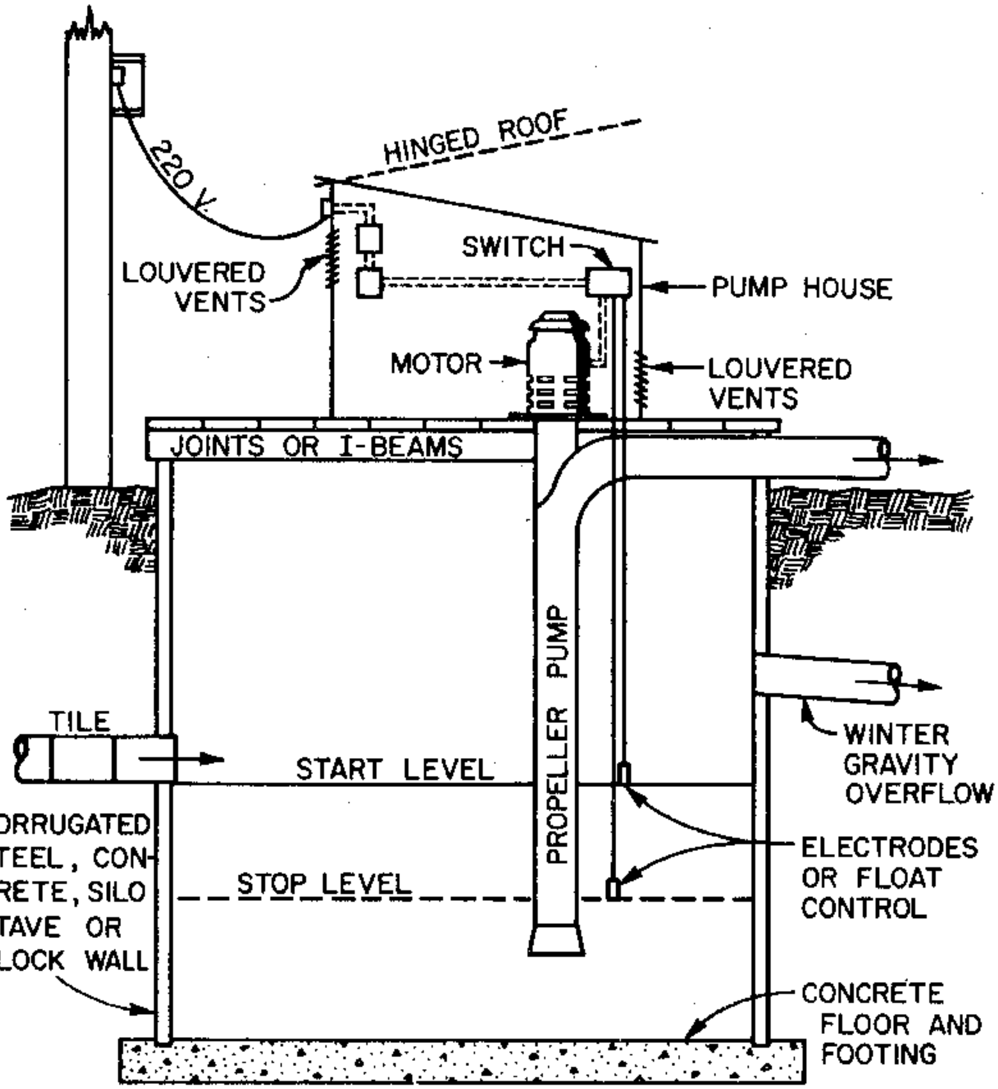


Figure 17 - Drainage pumping layout with storage sump.

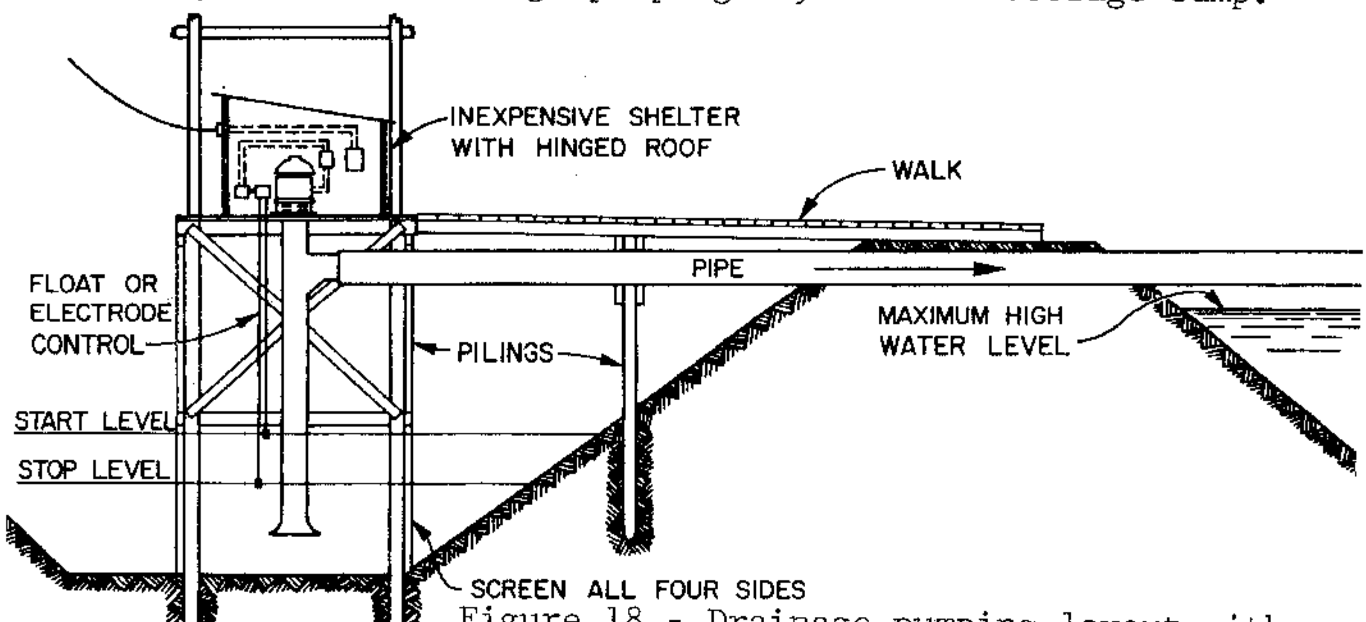


Figure 18 - Drainage pumping layout with storage ditch.

APPENDIX

TABLE X

SPECIFICATIONS FOR DRAINAGE MATERIALS

Type	Specification
Clay drain tile	ASTM[1/] C 4
Clay drain tile, perforated	ASTM C 498
Clay sewer pipe, standard strength	ASTM C 13
Clay pipe, extra strength	ASTM C 200
Clay pipe, perforated, standard and extra strength	ASTM C 211
Clay pipe, testing	ASTM C 301
Concrete drain tile	ASTM C 412
Concrete pipe for irrigation or drainage	ASTM C 118
Concrete pipe or tile, determining physical properties of	ASTM C 497
Concrete sewer, storm drain, and culvert pipe	ASTM C 14
Reinforced concrete culvert, storm drain, and sewer pipe	ASTM C 76
Perforated concrete pipe	ASTM C 444
Portland Cement	ASTM C 150
Asbestos-cement nonpressure sewer pipe	ASTM C 428
Asbestos-cement perforated underdrain pipe	ASTM C 508
Asbestos-cement pipe, testing	ASTM C 500
Homogeneous perforated bituminized fiber pipe for general drainage	ASTM D 2311
Homogeneous bituminized fiber pipe, testing	ASTM D 2314
Laminated-wall bituminized fiber perforated pipe for agricultural, land, and general drainage	ASTM D 2417
Laminated-wall bituminized fiber pipe, physical testing of	ASTM D 2315
Plastic drain and sewer pipe, styrene rubber	Commerical Standard 2
Perforations, if needed, are to be as specified in Fed. Spec. SS-P-358a	DS-228
Plastic drainage tubing, corrugated	Refer to Specifications Guide, page 606-11[3/]
Pipe, corrugated, aluminum allow	Federal Spec.[2/] WW-P-402a
Pipe, corrugated, iron or steel, zinc coated	Federal Spec. WW-P-00405
Pipe, bituminized fiber (and fittings)	Federal Spec. SS-P-1540

1/ American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

2/ Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

3/ Ohio Standards and Specifications for Conservation Practices,

Table XI - Runoff in CFS for Surface Drainage

ACRES DRAINED PER QUANTITY OF FLOW

Quantity cfs	Acres A	B	C	D	Quantity cfs	Acres A	B	C	D
1	3	7	12	18	41	136	254	593	1182
2	6	13	21	31	42	140	260	621	1220
3	10	19	30	44	43	143	267	649	1260
4	13	25	39	57	44	147	274	677	1300
5	16	31	48	70	45	150	281	705	1340
6	20	37	57	85	46	154	288	733	1380
7	23	43	66	100	47	157	295	761	1420
8	26	50	75	126	48	161	302	789	1460
9	30	55	84	132	49	164	309	817	1500
10	33	60	93	148	50	168	316	845	1540
11	36	66	102	164	52	175	331	900	1610
12	40	73	111	180	54	182	347	955	1680
13	43	79	120	208	56	190	362	1010	1750
14	46	85	130	226	58	197	378	1065	1820
15	50	91	141	245	60	204	393	1130	1890
16	53	97	152	269	62	211	413	1176	1960
17	56	103	163	293	64	218	433	1232	2030
18	60	109	175	317	66	225	453	1288	2100
19	63	115	187	341	68	232	473	1337	2170
20	66	120	198	365	70	239	492	1386	2240
21	70	127	209	401	72	246	519	1435	2317
22	73	131	223	437	74	253	545	1484	2394
23	76	139	237	474	76	260	571	1533	2471
24	80	145	251	510	78	267	598	1581	2548
25	83	150	265	550	80	274	625	1630	2624
26	86	156	279	590	82	281	659	1679	2701
27	90	162	283	630	84	288	693	1728	2778
28	93	169	307	670	86	295	727	1780	2854
29	97	175	321	710	88	302	761	1831	2931
30	100	182	335	750	90	310	795	1883	3008
31	103	188	356	790	92	318	830	1934	3085
32	107	195	377	830	94	326	864	1986	3162
33	110	201	398	870	96	334	899	2037	3238
34	113	208	419	910	98	342	933	2089	3315
35	117	214	440	949	100	350	968	2140	3392
36	120	220	465	988	105	373	1052	2269	3597
37	123	227	490	1026	110	397	1137	2398	3802
38	127	234	515	1065	115	420	1223	2526	4006
39	129	240	540	1104	120	443	1307	2655	4211
40	133	247	565	1143	125	467	1390	2784	4416

Table XI - Continued.

ACRES DRAINED PER QUANTITY OF FLOW

Quantity cfs	Acres A	Acres B	Acres C	Acres D
130	490	1473	2918	4621
135	518	1556	3053	4826
140	546	1639	3187	5030
145	573	1722	3322	5235
150	601	1805	3456	5440
155	629	1888	3592	5664
160	657	1980	3738	5888
165	701	2072	3878	6112
170	745	2165	4019	6336
175	788	2258	4160	6560
180	832	2350	4310	6784
185	875	2442	4442	7008
190	917	2535	4523	7232
195	960	2628	4724	7456
200	1004	2720	4864	7680
205	1048	2826	5019	7904
210	1092	2931	5172	8128
215	1136	3037	5326	8352
220	1180	3142	5479	8576
225	1224	3248	5633	8800
230	1268	3354	5787	9024
235	1312	3459	5940	9248
240	1364	3565	6094	9472
245	1416	3670	6247	9690
250	1468	3776	6400	9920
255	1520	3884	6560	10160
260	1572	3994	6720	10400
265	1624	4102	6880	10640
270	1676	4211	7040	10880
275	1728	4320	7200	11120
280	1786	4429	7360	11360
285	1844	4540	7520	11600
290	1903	4646	7680	11840
295	1961	4755	7840	12080
300	2019	4864	8000	12320
305	2077	4992	8160	12576
310	2135	5120	8320	12832
315	2193	5248	8480	13088
320	2252	5376	8640	13340
325	2310	5504	8800	13600
330	2368	5632	8960	13856
335	2432	5760	9120	14112
340	2496	5888	9280	14368
345	2560	6016	9440	14624
350	2624	6144	9600	14880
355	2688	6266	9766	15152
360	2752	6387	9933	15424
365	2816	6509	10097	15696
370	2880	6630	10266	15968
375	2955	6752	10432	16240
380	3029	6874	10598	16512
385	3104	6995	10765	16784
390	3179	7117	10931	17056
395	3253	7238	11098	17328
400	3328	7360	11264	17600

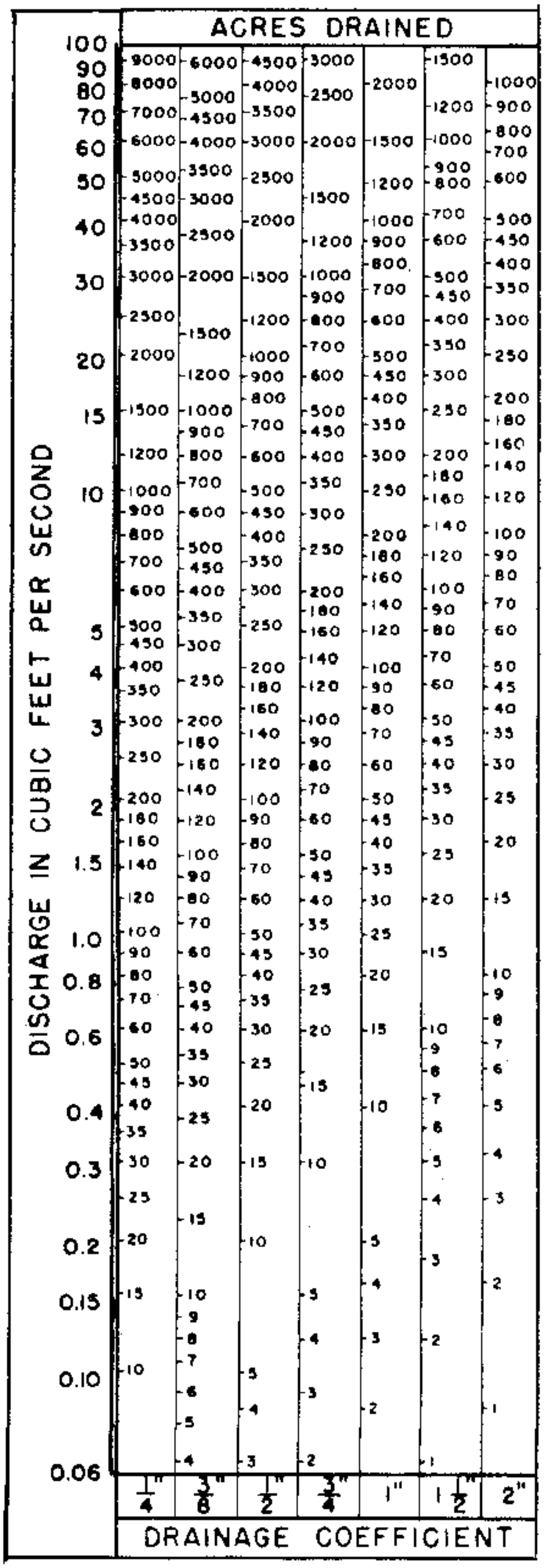
A - For good protection from flooding.

B - For excellent agricultural drainage.

C - For good agricultural drainage.

D - For fair agricultural drainage.

Table XII - Drainage CFS for Subsurface Drains



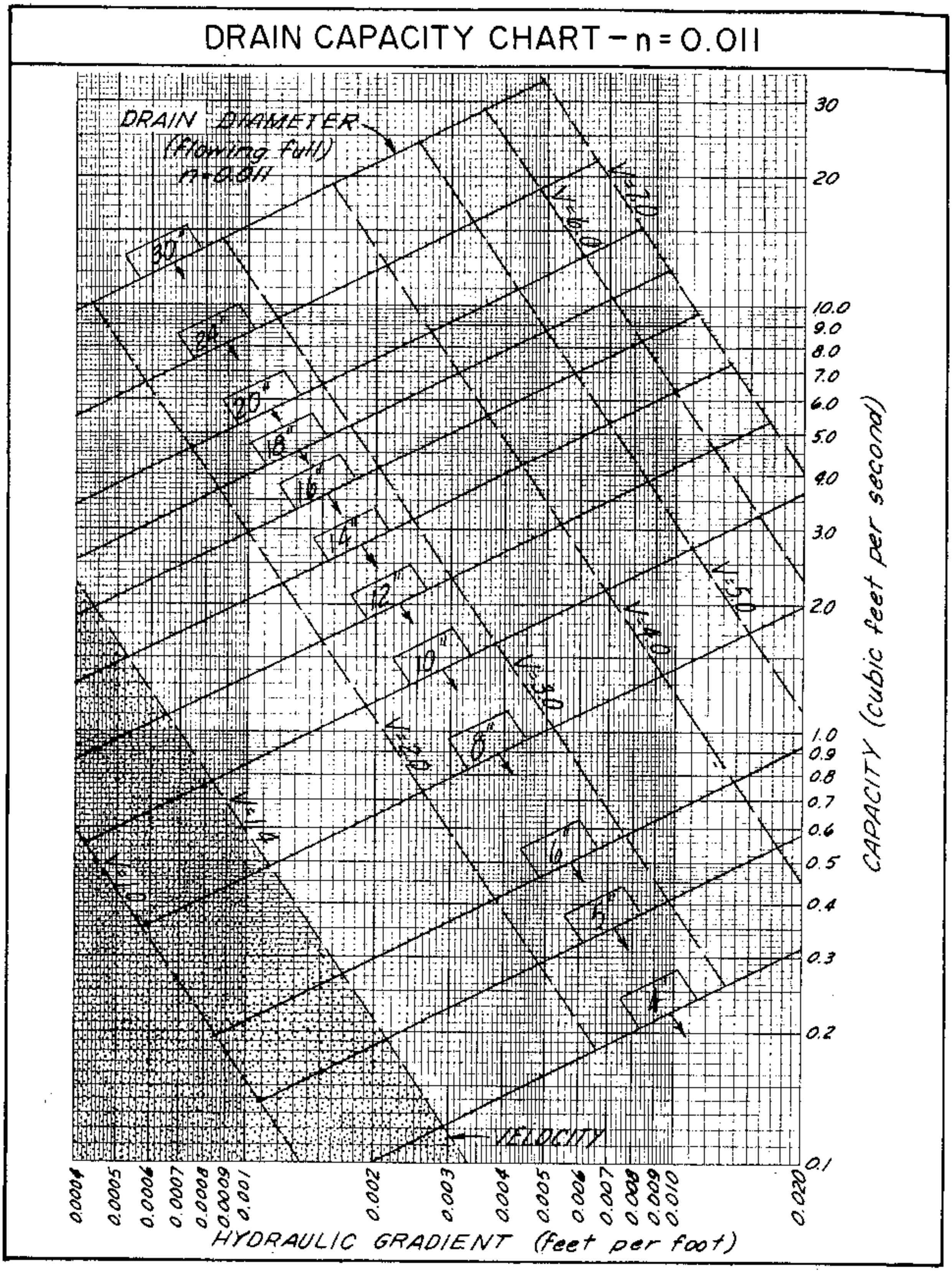


Figure 19 - For clay, concrete and bituminized pipe. (chart based on excellent tile alignment)

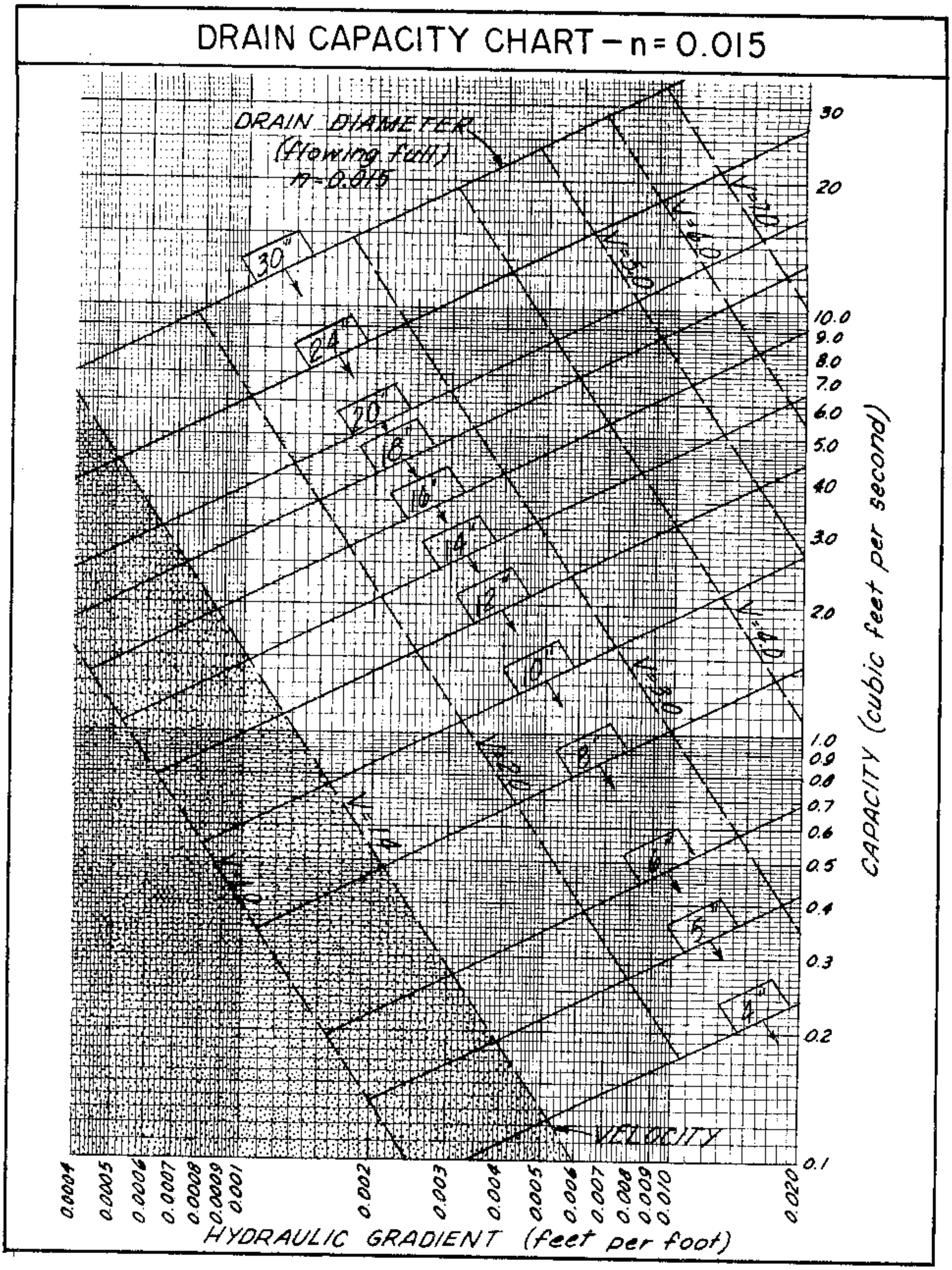


Figure 20 - For corrugated plastic drain tubing.

DRAIN CAPACITY CHART - n=0.025

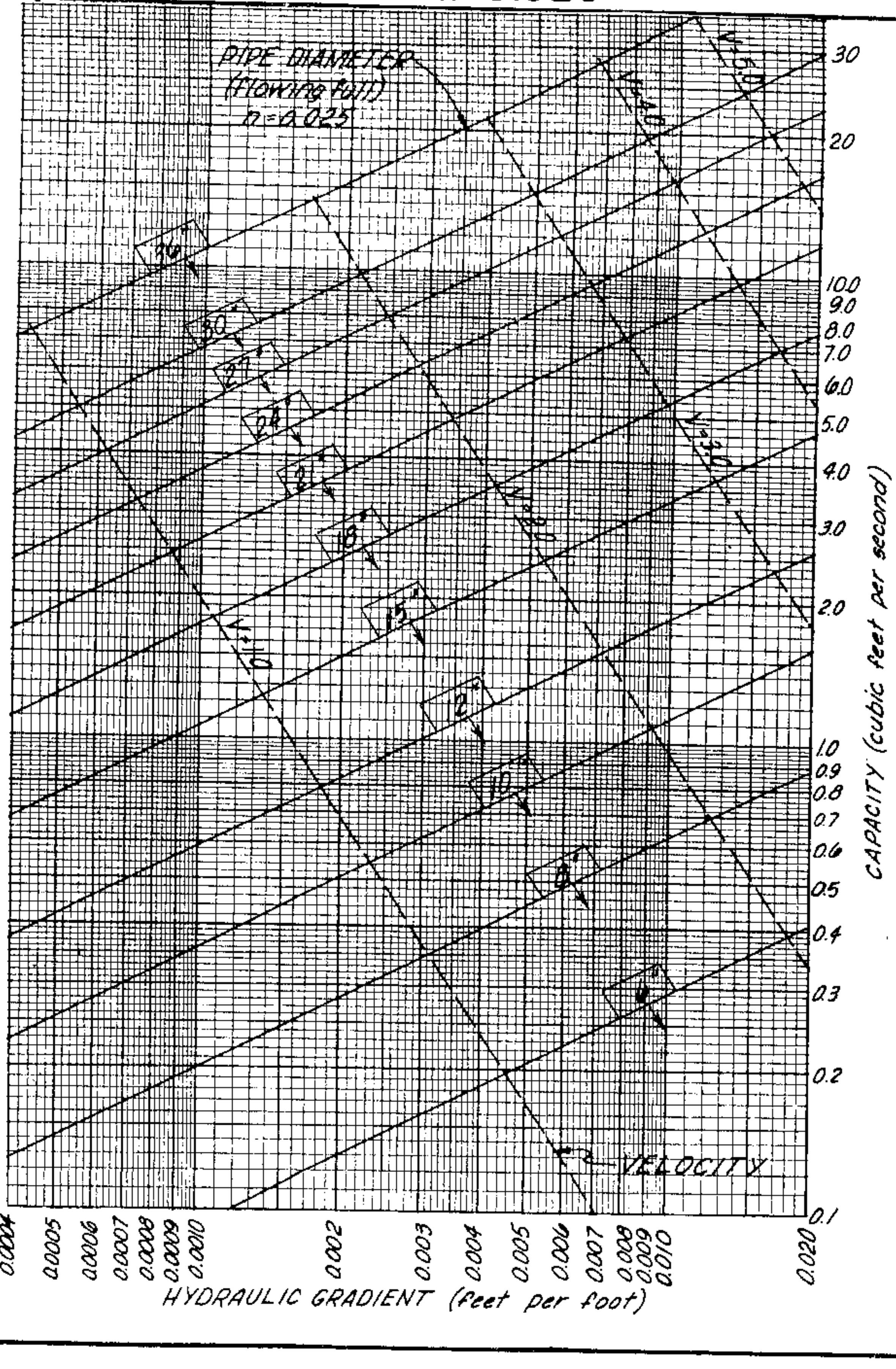


Figure 21 - For corrugated metal pipe.

Table XIII --Minimum Crushing Strength for Drain Tile (Pounds per Linear Foot) (Average of Five Tile)

Internal Diameter of Tile (inches)	Clay Drain Tile			Concrete Drain Tile	
	Standard	Extra Quality	Heavy Duty	Standard Quality	Extra and Special Quality
4	800	1,100	1,400	900	1,100
5	800	1,100	1,400	900	1,100
6	800	1,100	1,400	900	1,100
8	800	1,100	1,500	900	1,100
10	800	1,100	1,500	900	1,100
12	800	1,100	1,700	900	1,100
Refer to ASTM specifications for larger sizes.					

Table XIV --Guide for Using Concrete Tile in Acid Soils

Standard and Class of Tile	Lowest Permissible pH Values[1/]	
	Organic and Sandy Soils	Medium and Heavy-textured Soils
ASTM C 412:		
Standard quality	6.5	6.0
Extra quality	6.0	5.5
Special quality	5.5	5.0
ASTM C 14, C 118, C 444	5.5	5.0

1/Figures given represent lowest readings of pH values for soil water or soil at tile depth.

Table XV --Percent of Wheel Loads Transmitted to Underground Drains

Depth of Backfill Over Drain in Feet	Trench Width in Feet				
	1	2	3	4	5
1	17.0	26.0	28.6	29.7	29.9
2	8.3	14.2	18.3	20.7	21.8
3	4.3	8.3	11.3	13.5	14.8
4	2.5	5.2	7.2	9.0	10.3
5	1.7	3.3	5.0	6.3	7.3
6	1.0	2.3	3.7	4.7	5.5

Live loads transmitted are practically negligible below 6 feet. These percentages include both live load and impact transmitted to one linear foot of drain.

MAXIMUM ALLOWABLE TRENCH DEPTHS, RIGID CONDUITS

3-EDGE BEARING CRUSHING STRENGTH	TILE DIAMETER	TRENCH WIDTH (INCHES)							
		18	21	24	27	30	36	42	48
800	4,5,6	9	7	7	7	7	7	7	7
800	8	9	7	6	6	6	6	6	6
800	10	10	7	6	5	5	5	5	5
800	12		7	6	5	5	5	5	5
840	14			6	5	5	5	5	5
870	15			6	5	5	5	5	5
1000	6	19	9	8	8	8	8	8	8
1000	8	19	9	7	7	7	7	7	7
1100	4,5,6	25+	11	9	9	9	9	9	9
1100	8	25+	11	8	7	7	7	7	7
1100	10	25+	11	8	7	6	6	6	6
1100	12		11	8	7	6	6	6	6
1100	15			8	7	5	5	5	5
1150	15			9	7	6	5	5	5
1200	12		14	9	7	6	6	6	6
1200	16			10	8	7	5	5	5
1200	18				8	7	5	5	5
1250	4,5,6	25+	16	11	11	11	11	11	11
1300	4,5,6	25+	18	11	11	11	11	11	11
1300	8	25+	18	11	8	8	8	8	8
1300	18				9	7	5	5	5
1350	8	25+	22	11	9	9	9	9	9
1400	4,5,6	25+	25+	12	10	10	10	10	10
1400	10	25+	25+	12	9	8	8	8	8
1400	15			13	9	8	6	6	6
1450	4,5,6	25+	25+	13	11	11	11	11	11
1500	8	25+	25+	14	10	9	9	9	9
1500	12			14	10	8	7	7	7
1550	10	25+	25+	15	11	9	8	8	8
1600	4,5,6	25+	25+	16	12	12	12	12	12
1600	8	25+	25+	16	11	10	10	10	10
1600	10	25+	25+	17	11	9	9	9	9
1600	14			17	12	8	7	7	7
1650	15			19	12	10	7	7	7
1700	8	25+	25+	25	12	11	11	11	11
1700	12			25	12	10	8	8	8
1700	16			25	13	11	8	7	7
1700	18				13	11	8	7	7
1750	15			25	14	11	8	7	7
1800	8	25+	25+	25+	14	11	8	8	8
1800	12			25+	15	11	8	7	7
1800	18				15	11	8	7	7
1850	14				15	11	8	8	8
2000	4,5,6	25+	25+	25+	19	14	14	14	14
2000	8	25+	25+	25+	19	12	12	12	12
2000	10		25+	25+	19	13	10	10	10
2000	18				20	14	9	7	7

Based on: K_u & $K_{u'}$ = 0.13, Load Factor 1.5, Safety Factor 1.5, weight of soil - 120 lb./cu.ft.

Table XVI

GLOSSARY OF TERMS

Subsurface Drainage - The removal of excess water from below the soil surface by means of drain tile, perforated pipe, mole channels, or other devices.

Surface Drainage - The diversion or orderly removal of excess water from the surface of the land by means of improved natural or constructed channels, supplemented when necessary by sloping and grading of land surfaces to these channels.

Field Drain (Field Ditch) - A shallow, graded channel, usually having relatively flat side slopes, that collects water within a field. Water may enter it through crop rows or row ditches or by sheet flow over field surfaces.

Land Smoothing - Shaping the land surface with a land plane or land leveler to eliminate minor depressions and irregularities without changing the general topography. The depth of cut in this operation is generally small and limited by the kind of equipment used. Land smoothing is also the finished operation in land grading.

Land Grading - The shaping of the land surface by cutting, filling and smoothing to planned grades so that each row or surface slopes to a drain without ponding.

Water Table - The upper surface of a saturated zone within the soil.

Outlet - The lower terminal point of a drainage system or individual drain.

Drainage Coefficient - The depth of water, in inches, to be removed from an area in 24 hours.

Drain Invert - The lowest part of the internal cross-section of a lined channel or pipe.

Berm - A strip or area of land, usually level, between the spoil bank and edge of a ditch.

Diversion - A channel constructed across the slope to intercept surface runoff and conduct it to a safe outlet.

Bedding - Plowing, blading or otherwise elevating the surface of flat land into a series of broad, low ridges separated by shallow, parallel dead furrows or field ditches.

CFS - Cubic feet per second.

Conversion Table - American vs Metric

1 inch	= 2.54 cm.
1 foot	= 30.48 cm. = 0.3048 m.
1 mile	= 1609.3 m. = 1.609 km.
1 meter	= 39.37 in. = 3.281 ft.
1 kilometer	= 3280.8 ft. = 0.621 mi.
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1 gallon	= 3.785 liters
1 cubic foot	= 7.481 gal. = 28.32 liters
1 liter	= 0.2642 gal.
1 cubic meter	= 264.2 gal. = 35.32 cu.ft.
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1 acre	= 43,560 sq.ft. = 0.4047 hectare
1 square mile	= 640 acres - 259 hectares
1 hectare	= 2.471 acres
1 sq. kilometer	= 100 hectares - 247.1 acres

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